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CERTIFIED MAIL
RETURN RECEIPT REQUESTED

March 24, 2016

Ms. Susan Mackert
Virginia Department of Environmental Quality
Northern Regional Office
13901 Crown Court
Woodbridge, VA 22193

RE: Possum Point Power Station VPDES Permit No. VA0002071: CER for the Internal Outfall 503 Wastewater Treatment System

Dear Ms. Mackert:

Enclosed is a revised Concept Engineering Report (CER) for the Wastewater Treatment System that Dominion is planning to utilize to treat wastewaters generated during the ash pond closure project at the Power Point Power Station. The CER amendment submitted by my March 11, 2016 cover letter has been updated to address DEQ comments as follows:

1. Part 1.2, third paragraph - added that Pond D has not been discharged to date.
2. Section 1.2.1, first paragraph- added wastewaters are temporarily stored "***in Ash Pond A, B, C, D, or E (as later discussed)***".
3. Section 1.2.1, third paragraph- added ***Treatment processes required during the Decanting and Dewatering Stages are summarized in Table 1***.
4. Section 1.3.4, first paragraph- indicated Metals Cleaning Waste Treatment Facility ***is*** currently ***permitted to*** receive stormwater…"
5. Section 1.3.4, last paragraph- indicated that Outfall 501 was ***last*** discharged to Ash Pond E for storage in mid-April ***2015***.
6. Part 2.1, first paragraph- revised last sentence to "Any wastewater that is conveyed from one pond to another will continue to be filtered to remove CCRs ***prior to conveyance.***
7. Section 2.1.2, first paragraph- revised sentence to "During the Interim Configuration Phase, Dewatering Water from Ash Ponds A, B, C, D, and E is collected ***in temporary ponds*** from the installation of wells that pump water out of the ash and the excavation of trenches to drain the ash."
8. Section 2.1.2, first paragraph last sentence was changed to read "As of October 15, 2015 all Dewatering and Contact Waters from Ash Ponds A, B, C, and E are filtered to remove CCR material prior to being conveyed to Ash Pond D for storage~~***, in accordance with the VPDES permit***~~.
9. Part 3.0, first paragraph- changed "VDEQ-certified" reference to "***Virginia Environmental Laboratory Accreditation Program VELAP certified***".

10. Part 4.0, end of this section- added "***The Enhanced Treatment can likewise be turned off should inline process sampling determine that pollutant concentrations prior to Enhanced Treatment are below the trigger limits. Dominion reserves the right to operate the Enhanced Treatment system at any time, even if trigger limits have not been exceeded. A monthly report will be submitted to the DEQ which will provide dates when Enhanced Treatment was turned on or off. Process samples will be grab samples and will be analyzed using methods that will achieve the Quantification Levels (QLs) specified in the VPDES permit.***"
12. Part 5.1, third paragraph- removed "***maximum six-inch***" relating to the drawdown of Pond D.
13. Part 5.1, fourth paragraph- specified "hydrochloric acid or caustic soda for ***small*** pH adjustment ***to maintain effluent pH limitations***, as needed."
14. Section 5.1.3, added sentence "***Geotubes are engineered geotextile bags that retain particulate solids for disposal.***"
15. Part 5.2, first paragraph- added sentence "***Internal Outfall 503 will be after the required treatment and the temporary storage***".
16. Part 5.2, second paragraph- revised sentence "Should Dominion need to conduct metals cleaning operations when the Metals Ponds are offline, a frac tank or other ***temporary*** storage will be used***, and transported for offsite treatment and disposal***".
17. Figure 3
    a. revised "Sodium sulfite" to "Sodium ***sulfide***"
    b. added sodium sulfide, hydrochloric acid, and caustic soda to alternate flow paths prior to effluent pump.
    c. added Internal Process Monitoring Point.

Please contact Ken Roller of my staff at (804) 273-3494 or by email at kenneth.roller@dom.com should you have any questions or require additional information about this transmittal.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations

Sincerely,

Jason E. Williams
Manager, Electric Environmental Services

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Concept Engineering Report Internal Outfall 503 Wastewater Treatment System

Virginia Electric and Power Company
Possum Point Power Station
Coal Combustion Residual Surface Impoundment Closures
Dumfries, Virginia

GAI Project Number: C150132.00
March 2016

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1.0 Project Overview

1.1 Introduction

Virginia Electric and Power Company d/b/a Dominion Virginia Power (Dominion) is in the process of implementing a long-term strategy for closure of its existing coal combustion residual (CCR) ash ponds at the Possum Point Power Station (Station), an 1,845 megawatt natural gas and oil fired (previously coal-fired) steam electric generating station near Dumfries, Prince William County, Virginia (VA).

1.2 Project Description

Dominion is currently working to close five existing ash ponds at the Station: Ash Ponds A, B, C, D, and E. All five ponds are scheduled for closure by April 2018 in accordance with the relevant provisions of the United States Environmental Protection Agency's CCR rule, which was published on April 17, 2015, and codified in 40 Code of Federal Regulations (CFR) Part 257, Subpart D. A drawing showing the site location is shown in Figure 1.

Ash Ponds A, B, and C were originally three contiguous ponds that have been inactive since the 1960s. Ash Ponds A, B, C, and E have been decanted and are being dewatered until all ash material has been removed, in accordance with applicable state and local requirements. Dredged ash material from the ponds was initially transported to Ash Pond D for storage. Diversion of dredged ash to Ash Pond D ceased in October 2015; all remaining ash will be hauled to a permitted landfill for disposal.

Ash Pond D is scheduled to be decanted, dewatered, regraded, capped, and closed in the coming months; although for this project Pond D has not been discharged to date. During the decanting and dewatering process, water from Ash Pond D will be treated and discharged to Outfall 001/002 via Internal Outfall 503. Following dewatering, Ash Pond D will be converted to a single regulated solid waste facility subject to all applicable state and federal closure and post-closure care requirements.

The purpose of this document is to identify conceptual treatment and handling/discharge options for wastewater produced during the Interim Configuration Phase during construction of the ash pond closure project. The proposed conceptual treatment system has been designed to achieve substantial pollutant reductions and is expected to outperform the limits at Internal Outfall 503 set forth in the recently modified VA Pollutant Discharge Elimination System (VPDES) Permit No. VA0002071. Development of the proposed conceptual treatment system was based on best engineering judgement using water quality data presented in this report. The installed treatment system will be reviewed by a Professional Engineer for conformance to the conceptual design of this Concept Report and a certification will be provided to the VA Department of Quality (VDEQ).

The closure of Ash Ponds A, B, C, D, and E and handling of the remaining wastewaters as a result of the closures will be performed in two phases as described below:

1.2.1 Interim Configuration Phase (During Construction)

The Interim Configuration Phase during construction comprises the activities associated with closure of the Ash Ponds. During this phase, wastewaters are temporarily stored in Ash Pond A, B, C, D, or E, (as later discussed), treated to meet effluent limitations, and discharged in accordance with the permit conditions. Wastewaters include Pond D Comingled Water (i.e., surface waters to be decanted from Pond D to allow for closure) as well as Dewatering and Contact Waters from Ponds A, B, C, D, and E. These wastewater sources are described in more detail in Section 2.1 of this report.

Treatment of wastewaters will be conducted in two stages during the Interim Configuration Phase: 1) decanting of Pond D Comingled Water and 2) dewatering ash in Ponds A, B, C, D, and E. The Decanting Stage refers to the drawdown, treatment, and discharge of surface waters presently stored in Ash Pond D above the ash material. The Dewatering Stage refers to the removal of ash pore water (i.e., Ash Dewatering Water) and stormwater in contact with ash (i.e., Contact Water) from Ash Ponds A, B, C, D, and E and the treatment and discharge of these wastewaters in accordance with the permit conditions.

During the Decanting Stage, treatment will include the following processes: aeration, chemical addition/flocculation, settling with geotubes, and filtration with sand and bag filters. It is anticipated that pollutant concentrations will increase as Pond D surface waters (i.e., Comingled Waters) are drawn down during the Decanting Stage. Dominion has established very stringent pollutant concentration triggers for determining when to route water through Enhanced Treatment, as defined and described in Section 4.0 below. Treatment processes required during the Decanting and Dewatering Stages are summarized in Table 1.

1.2.2 Final Configuration Phase (Post-Construction)

The Final Configuration Phase post-construction comprises collection and treatment of final wastewaters as a result of the closed Ash Ponds from the Interim Configuration Phase during construction. The Final Configuration Phase will include treatment of capped Ash Pond D Underdrainage, existing metals cleaning wastewater (i.e., Outfall 501 Water), and Ash Pond Toe Drainage. The treatment system that will be employed during the Final Configuration Phase will be similar in design and operation to the system used during the Interim Configuration Phase but will be sized for a smaller flowrate. As such, the treatment system for these discharges will be addressed in a separate Concept Engineering Report for the Final Configuration Phase for approval.

1.3 Location and Description of Selected Project Facilities

Descriptions and locations of facilities associated with the Interim Configuration Phase during construction are provided in the following sections. All facility locations and descriptions are based on pre-construction conditions, except where noted.

1.3.1 Ash Ponds A, B, and C

Ash Ponds A, B, and C are located approximately 2,100 feet south of Ash Pond D, on the eastern bank of Quantico Creek. These ponds were actively used from the period between 1955 and the early 1960s.

Dominion plans to close Ash Ponds A, B, and C by removing all ash in the impoundments. Initially, dredged ash material from Ash Ponds A, B, and C was moved to Ash Pond D for storage. Transport of dredged ash materials from Ash Ponds A, B, and C to Ash Pond D for storage ceased in October 2015. Remaining ash material will be hauled to a permitted landfill for disposal. During closure construction activities, all Contact and Dewatering Water generated from Ash Ponds A, B, and C will be filtered and then diverted to Ash Pond D for temporary storage. Contact and Dewatering Water conveyed from Ash Ponds A, B, and C to Ash Pond D for storage was filtered for removal of CCR material beginning in October 2015.

1.3.2 Ash Pond D

Ash Pond D is the largest ash pond on the facility grounds and was constructed to provide storage for ash produced during coal-fired generation of electricity. Ash Pond D presently receives stormwater runoff from the surrounding watershed and filtered Contact and Dewatering Water from Ash Ponds A, B, C and E. Ash Pond D was previously authorized under the VPDES permit to discharge to Ash Pond E. There is currently no discharge from Ash Pond D.

Wastewaters from several sources are being, or have been, diverted to Ash Pond D for temporary storage. Wastewater sources include Decant Water, Dewatering and Contact Waters from Ash Ponds A, B, C, and E, as well as wastewater from the Station's Metals Cleaning Waste Treatment Facility (Outfall 501 Water) and Oily Waste Treatment Basin (Outfall 502 Water). All wastewaters that have been collected in Ash Pond D are referred to as "Pond D Comingled Water." Beginning in October 2015, Dewatering and Contact Water from Ash Ponds A, B, C, and E were filtered for removal of CCR material prior to being conveyed to Ash Pond D for storage.

1.3.3 Ash Pond E

Ash Pond E is located approximately 1,400 feet west of Ash Pond D. This pond was historically used as a day-to-day onsite ash pond. Following cessation of ash generating operations, the pond served as a final treatment system for various stormwater and process wastewaters generated by the Station. When active, Ash Pond E discharged via a riser structure to Outfall 005 in accordance with the VPDES permit.

Ash Pond E was decanted beginning in March 2015, prior to the initiation of the Ash Pond E dredging activities. A portion of the initial Decant Water was discharged via Outfall 005 in accordance with the VPDES permit. In April 2015, the riser structure was sealed and the remainder of the Decant Water was pumped to Ash Pond D. No discharges from Ash Pond E have occurred since the sealing of the riser structure in April 2015. Ash material was mechanically dredged from Ash Pond E to Ash Pond D from June 2015 to October 2015. All remaining ash material in Ash Pond E will be hauled to a permitted landfill for disposal.

1.3.4 Metals Cleaning Waste Treatment Facility

The Metals Cleaning Waste Treatment Facility consists of two lined ponds in series that accept and treat wastewater generated by the cleaning of the Station's boilers and other equipment. Treated effluent from the Metals Cleaning Waste Treatment Facility has historically been discharged to Ash Pond E via Internal Outfall 501 in accordance with the VPDES permit. The pond is currently permitted to receive stormwater and batch wastewater streams from cleaning/flushing activities at the following facilities:

- Boiler;
- Preheater;
- Economizer;
- Precipitator; and
- Associated piping.

The source for all cleaning/flush waters is raw, untreated water from the Potomac River. Outfall 501 was last discharged to Ash Pond E for storage in mid-April 2015. The Station does not anticipate metals cleaning waste will be conveyed to the Metals Cleaning Waste Treatment Facility in the immediate future. The Metals Cleaning Waste Treatment Facility is one of two proposed options for temporary storage prior to discharge of treated wastewaters associated with the Pond Closure Project.

2.0 Internal Outfall 503 Wastewater Sources

2.1 Interim Configuration Phase (During Construction)

Several wastewater sources will be conveyed to Ash Pond D for storage during the Interim Configuration Phase and these are described in the following sections. Although, beginning in October 2015, Dewatering and Contact Waters from Ash Ponds A, B, C, & E have been, and will continue to be, filtered to remove CCR material prior to being conveyed to Ash Pond D. For the purposes of this report, it has been assumed that all wastewaters will be stored in Ash Pond D prior to treatment. However, use of Ash Pond D as a temporary storage pond may cease during the Interim Configuration Phase to allow for the construction of a cap and liner system. In this scenario a temporary pond in Ash Pond E may be required. Any wastewater that is conveyed from one pond to another will continue to be filtered to remove CCRs prior to conveyance.

All wastewater sources (from Ponds A, B, C, D, & E) will be treated as described in Section 5.0 and subject to the triggers for Enhanced Treatment identified in Section 4.0. Treatment system effluent will then pass through temporary storage and be ultimately discharged to Outfall 001/002 via Internal Outfall 503.

2.1.1 Pond D Comingled Water

Ash Pond D has received and stored ash, Dewatering Water and Contact Water from Ponds A, B, C, and E, as well as discharges from the Metals Cleaning Waste Treatment Facility (i.e., Internal Outfall 501 Water) and Oil Water Treatment Basin (i.e., Internal Outfall 502 Water). The combined wastewaters stored in Ash Pond D are referred to as Pond D Comingled Water. Due to the large storage capacity of Ash Pond D, Pond D Comingled Waters has been given time for blending and settling of larger suspended solids.

Ash Dewatering and Contact Waters from Ash Pond E were conveyed to Ash Pond D beginning in April 2015. Dredged ash material from Ash Ponds A, B, C, and E to Ash Pond D ceased in October 2015. Remaining ash from these ponds will be hauled to a permitted landfill for disposal. Discharge of treated metals cleaning waste from Internal Outfall 501 was stopped in mid-April 2015 and is not planned in the immediate future. Discharge from Internal Outfall 502 was initially conveyed to Ash Pond D for storage but was rerouted on November 8, 2015, to permanently discharge via Outfall 004 in accordance with the VPDES permit. No ash from any pond has been placed in Ash Pond D since October 2015.

Pond D Comingled Water samples were collected on November 6 and November 13, 2015 to identify the water quality. Water quality data for Pond D Comingled Water (prior to treatment) compared with VDEQ permit limits for Internal Outfall 503 during the Interim Configuration Phase are shown in Table 2.

2.1.2 Dewatering and Contact Waters (Ponds A, B, C, D and E)

Dewatering Water refers to ash pore water that is collected from the dewatering of the ash in order to stabilize it and allow for its removal by mechanical dredging (i.e., for Ash Ponds A, B, C, and E) or its grading for the construction of a cap system (i.e., for Ash Pond D). During the Interim Configuration Phase, Dewatering Water from Ash Ponds A, B, C, D, and E is collected in temporary ponds from the installation of wells that pump water out of the ash and the excavation of trenches to drain the ash. Contact Water refers to all stormwater that comes in contact with ash. Contact Water must be removed from the working areas to close the ponds. As of October 15, 2015 all Dewatering and Contact Waters from Ash Ponds A, B, C, and E are filtered to remove CCR material prior to being conveyed to Ash Pond D for storage.

Dewatering Water samples from Ash Pond E were collected from several locations for analysis in May 2015. Sampling locations included Ash Pond E Rim Ditches and Well Point Discharges. Additionally, a sample of Well Point Discharges from Ash Pond E was collected by the Prince William County Service Authority (PWCSA) for separate analysis in July 2015. These samples were collected to evaluate anticipated water quality of Dewatering Waters. Water quality data for Dewatering Water (prior to any treatment or filtration) compared with VPDES permit limits for Internal Outfall 503 are shown in Table 3. It should be noted that all water from Ponds A, B, C and E has been subsequently (as of October 2015), and will continue to be, filtered prior to conveying to Ash Pond D. Consequently, the water quality data in Table 3 likely overestimates actual concentrations that will be present after filtration.

A Contact Water sample was collected from Ash Pond E on May 5, 2015 for analysis. This sample was collected to evaluate anticipated water quality of Contact Waters. Water quality data for Contact Water compared with VPDES permit limits for Internal Outfall 503 Phase are shown in Table 4. Again it should be noted that all Contact Water from Ponds A, B, C and E has been subsequently (as of October 2015), and will continue to be, filtered prior to conveying to Ash Pond D. Consequently, the water quality data in Table 4 likely overestimates actual concentrations that will be present after filtration.

3.0 Wastewater Characteristics

Dewatering and Contact Water samples were collected prior to implementing filtration of CCRs and analyzed, as previously discussed. Pond D Comingled Water samples were also collected and analyzed, as previously discussed. Samples were analyzed by a Virginia Environmental Laboratory Accreditation Program (VELAP)-certified laboratory for metals, total suspended solids, and other constituents that are parameters required for monitoring per the VPDES Permit. As previously discussed, results from these analyses are included in Tables 2 through 4. Each of these tables includes VPDES Permit effluent limitations for Internal Outfall 503 (when routed to Outfall 001/002) as a basis of comparison. Based on the water quality data presented in Tables 2 through 4, the following constituents have at least one sample with a concentration close to or exceeding the said VPDES Permit effluent limitation:

- Total Selenium;
- Total Suspended Solids;
- Total Nickel;
- Total Thallium;
- Total Arsenic;
- Total Copper; and
- Total Lead.

A summary of observed concentrations of these constituents and the related sampling locations are shown in Table 5. These samples are representative of raw, untreated wastewater from sources that include Ash Pond D Comingled Water as well as Dewatering and Contact Water samples from Ash Pond E that have not been filtered for CCR material. Dewatering and Contact Water samples from Ash Pond E were evaluated in order to assess expected constituent concentrations once Pond D Comingled Water has been removed from Ash Pond D and intake to the treatment system is entirely composed of Contact Water and Dewatering Water during the Dewatering Stage.

4.0 Treatability of Wastewater

Unit processes that have been incorporated into the conceptual treatment system include aeration, chemical addition/flocculation, settling with geotubes, filtration with sand and bag filters, alumina adsorption, and weak acid cation (WAC) exchange. An aeration step has been incorporated to facilitate the oxidation of metals prior to injecting with a flocculant. The additional chemical addition and flocculation step includes pH adjustment as needed, as well as injection of ferric chloride and a polymer to enhance coagulation. Flocculant and coagulant dosing will be determined based upon ongoing jar tests. Addition of sodium hypochlorite is also provided, as required, in the event chemical oxidation of arsenic is needed should addition of ferric chloride flocculant not be sufficient. The formed flocs are collected in the sediment tanks equipped with geotubes to dispose of collected solids. A filtration step allows for pretreatment and removal of fines prior to the additional metals polishing step. Alumina adsorption and WAC exchange will be used, as necessary, as described below (for purposes of this CER, the alumina adsorption and WAC exchange steps will be referred to as "Enhanced Treatment").

Adsorption using activated alumina has been incorporated into the conceptual treatment system to further polish dissolved arsenic and selenium concentrations. According to the American Water Works Association's "Water Quality and Treatment: A Handbook of Community Water Supplies," activated alumina can be used for removal of both arsenic and selenium, with suggested removal efficiencies ranging from 60 to 100 percent. Additionally, the Environmental Protection Agency has identified activated alumina as a best available technology for thallium removal and as a suitable treatment technology for arsenic removal.

Treatment with a WAC exchange resin was selected for additional removal of heavy metals as needed following flocculation/oxidation/settling, filtration, and activated alumina adsorption. At low metals concentrations similar to those observed in the Decanting, Contact and Dewatering Water samples, both weak and strong acid cation (SAC) exchange resins are capable of removing heavy metals. WAC exchange resins are recommended for applications where a variety of different heavy metals must be removed. WAC exchange resins offer an advantage over SAC exchange resins in terms of lower anticipated regeneration frequency while providing removals of targeted trace metals.

Treatment design parameters obtained from published literature from United States Environmental Protection Agency, American Water Works Association, Interstate Technology & Regulatory Council, as well as additional supporting documentation from third parties substantiates and qualifies the above unit processes for removal of constituents regulated by the VPDES Permit (Refer to Appendix A). Furthermore, a Treatability Study was performed to pre-select polymers to aid in metals removals for the chemical addition/flocculation and settling unit processes (Refer to Appendix B). This study for Possum Point evaluated solids removal efficiencies of a number of pre-selected cationic and anionic polymer applications suitable for representative samples of Dewatering Waters anticipated during the Pond Closure project. Thus, polymers that worked most effectively given the ash pond water quality characteristics were recommended for implementation. Conceptual polymer dosage ranges were characterized to allow for operational flexibility. The conclusion suggests that a large majority of metals and solids removals will be efficiently managed with the aeration, chemical addition/flocculation and settling unit processes.

If effluent from the treatment system exceeds any of the pollutant concentration triggers presented below, as determined by inline process sampling, then the effluent will be routed through Enhanced Treatment prior to being discharged:

- Arsenic – 100 ug/L
- Antimony – 640 ug/L
- Selenium – 5.0 ug/L

- Thallium – 0.47 ug/L
- Lead – 7.4 ug/L
- Copper – 6 ug/L

The Enhanced Treatment can likewise be turned off should inline process sampling determine that pollutant concentrations prior to Enhanced Treatment are below the trigger limits. Dominion reserves the right to operate the Enhanced Treatment system at any time, even if trigger limits have not been exceeded.

A monthly report will be submitted to the DEQ which will provide dates when Enhanced Treatment was turned on or off. Process samples will be grab samples and will be analyzed using methods that will achieve the Quantification Levels (QLs) specified in the VPDES permit.

5.0 Wastewater Treatment System Design Approach and Methods

5.1 Treatment System Description

All accumulated water in Ash Pond D (Decant, Contact Water, and Dewatering Water) will be treated for removal of total suspended solids, metals, and other constituents prior to discharge to Outfall 001/002 via Internal Outfall 503. All Ash Pond D Decant/Contact/Dewatering Water and contributing wastewater sources will be conveyed to a multiple-stage treatment system, as previously discussed. Enhanced Treatment will be used, as necessary, based on the trigger conditions set forth in Section 4.0. Treated effluent will be directed to temporary storage. A process flow diagram showing the routing of all wastewater for treatment and discharge to Outfall 001/002 is shown in Figure 2.

The proposed conceptual treatment system is designed for compliance with the effluent limitations established in the VPDES Permit and is based on water quality analyses of representative samples of wastewaters that will be generated during the pond closure project. A treatment process block flow diagram illustrating the conceptual treatment during the Interim Configuration Phase is shown in Figure 3. The conceptual treatment system design basis and Equipment General Arrangement are included in Appendix C.

During the Decanting Stage, Pond D Comingled Water will be decanted from Ash Pond D at a maximum flow rate of 2.88 MGD (2,000 gpm) with a drawdown per day in accordance with the VPDES permit. During the Dewatering Stage, wastewaters generated will likely be less than those produced during the Decanting Stage, and therefore, the discharges may be intermittent. However, the system will be capable of operating 24 hours a day, seven days a week at the maximum permitted flow rate of 2.88 MGD until the Interim Configuration Phase is completed.

Influent will be directed to aeration tanks equipped with blowers. Aeration will be applied to the influent wastewater to enhance oxidation of dissolved metals. The water will then be conveyed to two automated chemical addition/injection trailers for injection of ferric chloride to produce iron flocs for the removal of metals, polymeric flocculation aid to enlarge the iron flocs for increased metal removal, and hydrochloric acid or caustic soda for small pH adjustment to maintain effluent pH limitations, as needed. Sodium hypochlorite may also be injected as an oxidizing agent in case desired arsenic removals are not achieved through application of ferric chloride flocculant. Final product selection of polymeric flocculation aid shall be identified from jar testing. After chemical addition/flocculation, the water will be pumped into a settling basin that includes geotubes. Two transfer pumps will direct the water from the settling tanks to backwashing sand filter skids and bag filters in order to remove coarse and fine suspended sediment that passes through the settling basins/geotubes.

After filtration, Enhanced Treatment will be used, as necessary, based the trigger conditions set forth in Section 4.0. The first stage of additional metals treatment is activated alumina adsorption for removal of dissolved selenium and arsenic. After passing through the activated alumina adsorption vessels, additional metals treatment with WAC exchange resins will provide final polishing of other targeted metals.

The pH of the treated water may be adjusted with hydrochloric acid or caustic soda and dechlorinated with sodium sulfite, as needed, should sodium hypochlorite be added, as previously discussed. The treated water will be directed to temporary storage and then to Outfall 001/002 via Internal Outfall 503. Collected sludge from the settling basins/geotubes and spent bag filters and media will be hauled offsite for disposal in a permitted landfill.

Upon initial startup of the treatment system, treated effluent will be recycled back to Ash Pond D until the treatment system's efficacy has been established. After establishing efficacy, if effluent from the treatment system exceeds any of the pollutant concentration triggers presented in Section 4.0, as determined by inline process sampling, then the effluent will be routed through Enhanced Treatment. Once treatment system effluent concentrations have reached levels that are compliant with the VPDES Permit, treated effluent will be diverted to temporary storage and Internal Outfall 503 for discharge.

Specific unit processes are further described as follows.

5.1.1 Aeration Tanks

Aeration is provided via four 21,000-gallon tanks equipped with 40-horsepower blowers for mixing and initial pre-treatment/oxidation of metals.

5.1.2 Chemical Addition

The chemical addition/injection trailers will have automatic injection capabilities for coagulation, flocculation, oxidation, and pH adjustment. There will be two 10 gph injection pumps to provide ferric chloride and polymeric flocculation aid. It is estimated that ferric chloride will be injected at an initial dosage of 10 ppm, and that this dosage will be adjusted as necessary based on jar testing and/or actual performance. Required injection rates of the 20 percent by weight solution are estimated to be 4.2 and 3.7 gph at 2,000 and 1,750 gpm, respectively. Injection dosage and exact polymer to be injected for flocculation are still to be determined from jar testing. Injection for pH adjustment will be either hydrochloric acid, for lowering pH, or caustic soda, for raising pH levels, as needed. The pH adjustment will be incorporated prior to the settling basin/geotubes, as necessary. Dosage of the sodium hypochlorite oxidizing agent may be recommended should arsenic not be removed with ferric chloride flocculation, or if ferrous iron overwhelms the ion exchange resins. The trailers will also include an inline static mixer after chemical injection. Flocculation will also be provided in the chemical addition/injection trailers.

5.1.3 Settling Tank with Geotubes

A modular tank equipped with geotubes provides removal of flocs. Geotubes are engineered geotextile bags that retain particulate solids for disposal. The flocs/sludge collected in the settling tank and geotubes is to be hauled offsite for disposal in a permitted landfill.

5.1.4 Backwashing Sand Filters

The proposed sand filter system consists of six Carbonair Model 4-54 sand filters in parallel. Each model contains four 54-inch-diameter filters. Each sand filter unit will be backwashed with treated water for 10 minutes at a backwashing rate of approximately 250 gpm. During this backwashing period the total flow rate through all six of the sand filter units should be reduced to approximately 1,500 gpm. The sand filters are equipped with automated backwashing capabilities, and backwashing will be triggered when a differential pressure setpoint is exceeded. Backwash water can then be recycled to Ash Pond D for settling.

5.1.5 Bag Filters

The proposed bag filter system consists of four Krystil Klear Multi-Round Model 3636 bag filter housings in parallel. The bag filters have initially been selected with 0.5-micron nominal openings. Alternate opening sizes may be selected depending on treatment needs. Spent bag filters will be hauled offsite for disposal in a permitted landfill.

5.1.6 Activated Alumina

The proposed activated alumina system includes four Carbonair PC78 vessels in parallel. Each vessel includes 500 cu. ft. (20,000 lbs) of granular activated alumina. Assuming all dissolved arsenic is removed from pre-treatment upstream, the four vessels are expected to last through approximately 598.4 million gallons of water or 208 days of continuous operation at 2,000 gpm. Granular activated alumina will be replaced as needed. Enhanced Treatment will be used, as necessary, based on the trigger conditions set forth in Section 4.0.

5.1.7 WAC Exchange

Based on process water quality analyses, water may be conveyed to additional adsorption and/or ion exchange treatment processes to provide additional selective constituent removals (e.g., aluminum, barium, trivalent chromium, copper, iron, lead, nickel, thallium, zinc, etc.). The proposed WAC exchange system consists of four vessels in parallel. These vessels will be filled with 600 cu. ft. (28,000 lbs) of cation exchange resin specific to the desired metals removals. The resin usage rate is predicted to be approximately 40 cu. ft. per million gallons of water. All four vessels are predicted to require change-out every 60 million gallons of water or after 20 days of continuous operation at 2,000 gpm.

5.1.8 pH Adjustment/Dechlorinating

Following removal of metals through ion exchange and/or adsorption, treated water will be adjusted for pH again using hydrochloric acid or caustic soda, as needed. Sodium sulfite may be added for dechlorinating the water if sodium hypochlorite is used as an oxidizing agent. Dosage for sodium sulfite is to be determined based on sodium hypochlorite dosages.

5.1.9 Post Ion Exchange Bag Filters

Following removal of metals through WAC exchange and/or activated alumina adsorption, treated water will pass through one-micron nominal high efficiency bag filters as a preventative measure to catch sloughed-off particulates from the ion exchange unit processes. Spent bag filters will be hauled offsite for disposal in a permitted landfill.

5.2 Treated Wastewater Discharge

Treated wastewater will be routed to Internal Outfall 503 and ultimately Outfall 001/002 for discharge into Quantico Creek. This will require construction of a pipeline to divert water from the conceptual treatment system and temporary storage to Internal Outfall 503 and to Outfall 001/002. Internal Outfall 503 will be sampled for compliance with the VPDES permit after the required treatment and the temporary storage. The temporary storage of treated discharges will allow Dominion to sample and analyze the waters to identify VPDES Permit compliance prior to discharging to Internal Outfall 503. For treated water storage use of the lined Metals Cleaning Waste Treatment Facility Ponds or Storage Tanks are included. Locations for the treatment system and temporary storage are shown on Figure 4.

If the Metals Cleaning Waste Treatment Facility (Metals Ponds) are utilized as a temporary storage location, the ponds will be temporarily taken offline and not used for storage of metals cleaning waste associated with Internal Outfall 501. Should Dominion need to conduct metals cleaning operations when the Metals Ponds are offline, a frac tank or other temporary storage will be used, and transported for offsite treatment and disposal. Prior to use for temporary storage, the Metals Ponds will be emptied and cleaned. In addition, the existing liner system in the ponds will be visually inspected and approved for use by a Professional Engineer.

TABLES

Table 1
Unit Processes Required

Process	Decanting Stage	Dewatering Stage
Aeration	X	X
Chemical Injection / Flocculation	X	X
Settling with Geotubes	X	X
Sand Filtration	X	X
Bag Filtration	X	X
Activated Alumina Adsorption	A	A
WAC Exchange	A	A

Footnotes:

X: Process to be used during treatment.

A: Enhanced Treatment will be used, as necessary, based on the trigger conditions set forth in Section 4.0.

Table 2
Possum Point Pond D Comingled Water Compared with VPDES Permit Limits for Internal Outfall 503

		VPDES Permit Limits				Pond D Comingled Water									
		Internal Outfall 503 - When Routed to 001/002 or 004				Pond D 6A	Pond D 6B	Pond D 6C	Pond D 7A	Pond D 7A	Pond D 7B	Pond D 7C	Pond D 8A	Pond D 8B	Pond D 8C
Parameters	**Units**	**Monthly Average**	**Daily Maximum**	**Minimum**	**Maximum**	**11/6/15**	**11/6/15**	**11/6/15**	**11/6/15**	**11/13/15**	**11/13/15**	**11/13/15**	**11/13/15**	**11/13/15**	**11/13/15**
pH [1]	**S.U.**	N/A	N/A	**6.0**	**9.0**	7.97	7.93	7.86	7.94	NA	7.74	7.85	7.79	7.74	7.78
Total Suspended Solids (TSS)	**mg/L**	**30**	**100**	N/A	N/A	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	5
Oil and Grease (O&G)	**mg/L**	**15**	**20**	N/A	N/A	4.0	4.6	5.0	6.9	NA	0.51±	< 2.1	< 2.0	< 2.0	< 2.0
Aluminum, Total	**ug/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aluminum, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony, Total	**ug/L**	**1,300**	**1,300**	N/A	N/A	4.1	4.1	3.8	3.9	NA	3.8	3.8	3.7	4.0	3.7
Antimony, Dissolved	ug/L	N/A	N/A	N/A	N/A	4.1	3.9	4.0	3.7	4.1	3.8	3.8	3.7	3.8	3.7
Arsenic, Total	**ug/L**	**240**	**440**	N/A	N/A	17	17	15	17	NA	16	15	16	16	15
Arsenic, Dissolved	ug/L	N/A	N/A	N/A	N/A	16	15	15	15	15	15	14	14	15	15
Barium, Total	**ug/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Barium, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Beryllium, Total	**ug/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Beryllium, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Boron, Total	**ug/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Boron, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium, Total	**ug/L**	**1.4**	**2.6**	N/A	N/A	< 0.50	< 0.50	< 0.50	< 0.50	NA	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Cadmium, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Chloride	**µg/L**	**370,000**	**670,000**	N/A	N/A	73,600	73,700	74,100	73,400	NA	75,500	75,800	76,200	76,100	76,300
Chromium III, Total	**ug/L**	**88**	**160**	N/A	N/A	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Chromium III, Dissolved [2]	ug/L	N/A	N/A	N/A	N/A	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Chromium VI, Total [3]	**µg/L**	**17**	**32**	N/A	N/A	0.14±	0.14±	0.14±	0.13±	0.086±	0.089±	0.086±	0.098±	0.086±	0.084±
Chromium VI, Dissolved	µg/L	N/A	N/A	N/A	N/A	0.12±	0.11±	0.12±	0.11±	< 0.25	< 0.25	< 0.25	0.072±	< 0.25	< 0.25
Cobalt, Total	**µg/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper, Total	**µg/L**	**9.6**	**18**	N/A	N/A	1.9±	1.8±	1.6±	1.7±	NA	0.97±	0.90±	0.87±	0.87±	< 2.5
Copper, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Iron, Total	**ug/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Iron, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead, Total	**µg/L**	**14**	**26**	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	NA	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Lead, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Mercury, Total	**µg/L**	**1.2**	**2.2**	N/A	N/A	< 0.20	< 0.20	< 0.20	< 0.20	NA	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Mercury, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 0.20	0.35	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20

Table 2 (continued)
Possum Point Pond D Comingled Water Compared with VPDES Permit Limits for Internal Outfall 503

		VPDES Permit Limits				Pond D Comingled Water									
		Internal Outfall 503 - When Routed to 001/002 or 004				Pond D 6A	Pond D 6B	Pond D 6C	Pond D 7A	Pond D 7A	Pond D 7B	Pond D 7C	Pond D 8A	Pond D 8B	Pond D 8C
Parameters	**Units**	**Monthly Average**	**Daily Maximum**	**Minimum**	**Maximum**	**11/6/15**	**11/6/15**	**11/6/15**	**11/6/15**	**11/13/15**	**11/13/15**	**11/13/15**	**11/13/15**	**11/13/15**	**11/13/15**
Molybdenum, Total	**µg/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Molybdenum, Dissolved	µg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nickel, Total	**µg/L**	**24**	**44**	N/A	N/A	5.5	5.3	4.9	5.5	NA	4.9	4.8	4.5	4.6	4.4
Nickel, Dissolved	µg/L	N/A	N/A	N/A	N/A	4.6±	5.3	4.5±	4.6±	4.6±	4.5±	4.5±	4.2±	4.7±	4.3±
Selenium, Total	**µg/L**	**8.0**	**15**	N/A	N/A	7.4	6.7	6.3	6.7	NA	5.6	5.4	5.6	5.7	5.4
Selenium, Dissolved	µg/L	N/A	N/A	N/A	N/A	6.3	5.2	6.3	5.4	6.4	5.8	5.9	6.1	5.8	6.3
Silver, Total	**µg/L**	**2.2**	**4.0**	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	NA	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Silver, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Thallium, Total	**µg/L**	**0.94**	**0.94**	N/A	N/A	0.38±	0.39±	0.35±	0.38±	NA	0.40±	0.39±	0.39±	0.40±	0.37±
Thallium, Dissolved	µg/L	N/A	N/A	N/A	N/A	0.48±	0.40±	0.39±	0.39±	0.42±	0.39±	0.37±	0.36±	0.37±	0.39±
Vanadium, Total	**µg/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium, Dissolved	µg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zinc, Total	**µg/L**	**98**	**180**	N/A	N/A	< 2.5	0.91±	< 2.5	< 2.5	NA	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5
Zinc, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0	6.8	< 5.0	3.9±	< 5.0	< 5.0	< 5.0	< 5.0	5.3	< 5.0
Hardness, Total (as $CaCO_3$)	**mg/L**	**NL**	**NL**	N/A	N/A	150	150	159	158	NA	155	155	154	157	144
Total Nitrogen	**mg/L**	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Kjeldahl Nitrogen	**mg/L**	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate+Nitrite (NO_3+NO_2), as N	**mg/L**	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ammonia, as N	**mg/L**	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acute Toxicity – *C. dubia* [(4)]	**% NOEC**	N/A	N/A	**100%**	N/A	NA	NA	100%	NA	NA	NA	NA	NA	NA	NA
Acute Toxicity – *P. promelas* [(4)]	**% NOEC**	N/A	N/A	**100%**	N/A	NA	NA	100%	NA	NA	NA	NA	NA	NA	NA
Chronic Toxicity – *C. dubia* [(5)]	**TU_c**	N/A	N/A	N/A	**2.85**	NA	NA	1.0	NA	NA	NA	NA	NA	NA	NA
Chronic Toxicity – *P. promelas* [(5)]	**TU_c**	N/A	N/A	N/A	**2.85**	NA	NA	1.0	NA	NA	NA	NA	NA	NA	NA

Footnotes:

1 Values preceded by "<" represent results not detected at the Reporting Detection Limit (RDL) and listed as < RDL.
2 Values with suffix "±" represent results with an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte.
3 NA- Not analyzed.
4 mg/L - milligrams per liter.
5 µg/L- micrograms per liter.
6 NL = No Limit.
7 Reported as No Observed Effect Concentration (NOEC); 100 percent NOEC is required for Acute Toxicity tests.
8 Reported as Chronic Toxicity Units; A maximum of 2.85 Chronic Toxicity Units allowed for Chronic Toxicity Results.
9 VPDES Permit limits for comparison are for the discharge of Outfall 503 to Outfall 001/002.
10 Where Reporting Detection Limit (RDL) of dissolved metals exceeds total metals, the lab diluted the sample to obtain a result thus increasing the Limit of Quantitation (LOQ) and RDL by the factor of dilution.

Table 3
Possum Point Dewatering Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond E Rim Ditch			Pond E Well Points					
		Internal Outfall 503 - When Routed to 001/002 or 004				RMD-1	RMD-2	RMD-3	Well Discharge 1	Well Discharge 2	Well Discharge 3	Well Discharge 3 dup	PWCSA Sample	GAI Duplicate Sample
		Monthly Average	Daily Maximum	Minimum	Maximum	5/5/2015	5/6/2015	5/11/2015	5/11/2015	5/12/2015	5/13/2015	5/13/2015	7/30/2015	7/30/2015
pH [(1)]	**S.U.**	N/A	N/A	**6.0**	**9.0**	7.85	8.00	8.08	7.77	7.88	7.76	7.81	8.15	7.32
Total Suspended Solids (TSS)	**mg/L**	**30**	**100**	N/A	N/A	26	159	44	34	19	20	26	42	27
Oil and Grease (O&G)	**mg/L**	**15**	**20**	N/A	N/A	< 2.0	1.7±	1.1±	1.4±	< 2.0	< 2.0	< 2.0	NA	NA
Aluminum, Total	**ug/L**	**NL**	**NL**	N/A	N/A	NA	17,800	NA	NA	59	NA	NA	NA	NA
Aluminum, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	260	NA	NA	< 80	NA	NA	NA	NA
Antimony, Total	**ug/L**	**1,300**	**1,300**	N/A	N/A	4.3	14	2.7	< 1.0	< 1.0	< 1.0	< 1.0	NA	NA
Antimony, Dissolved	ug/L	N/A	N/A	N/A	N/A	3.9	16	2.5	< 2.0	< 2.0	< 2.0	< 2.0	NA	NA
Arsenic, Total	**ug/L**	**240**	**440**	N/A	N/A	51	370	260	1,100	920	1,200	1,200	390	330
Arsenic, Dissolved	ug/L	N/A	N/A	N/A	N/A	24	240	180	880	810	900	840	< 50	51
Barium, Total	**ug/L**	**NL**	**NL**	N/A	N/A	220	830	290	400	330	420	410	NA	NA
Barium, Dissolved	ug/L	N/A	N/A	N/A	N/A	180	250	240	370	360	380	360	NA	NA
Beryllium, Total	**ug/L**	**NL**	**NL**	N/A	N/A	NA	7.2	NA	NA	< 0.50	NA	NA	< 4.0	0.30±
Beryllium, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	0.11±	NA	NA	< 1.0	NA	NA	< 50	0.18±
Boron, Total	**ug/L**	**NL**	**NL**	N/A	N/A	NA	1,000	NA	NA	1,300	NA	NA	NA	NA
Boron, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	1,000	NA	NA	1,400	NA	NA	NA	NA
Cadmium, Total	**ug/L**	**1.4**	**2.6**	N/A	N/A	< 0.5	0.55	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 50	0.27±
Cadmium, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 50	< 1.0
Chloride	**µg/L**	**370,000**	**670,000**	N/A	N/A	176,000	191,000	173,000	234,000	251,000	247,000	240,000	NA	NA
Chromium III, Total	**ug/L**	**88**	**160**	N/A	N/A	NA	NA	0.90±	< 1.0	< 1.0	< 1.0	< 1.0	< 50	< 1.0
Chromium III, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 10	NA	0.95±	2.6	2.4	2.5	2.5	< 50	2.0±
Chromium VI, Total	**µg/L**	**17**	**32**	N/A	N/A	0.096±	0.069±	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	NA	NA
Chromium VI, Dissolved	µg/L	N/A	N/A	N/A	N/A	0.095±	0.072±	NA	NA	< 0.25	< 0.25	< 0.25	NA	NA
Cobalt, Total	**µg/L**	**NL**	**NL**	N/A	N/A	NA	16	NA	NA	1.8±	NA	NA	NA	NA
Cobalt, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	< 5.0	NA	NA	2.2±	NA	NA	NA	NA
Copper, Total	**µg/L**	**9.6**	**18**	N/A	N/A	3.6	84	4.7	1.0±	< 2.5	0.85±	0.84±	< 50	2.1±
Copper, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0	< 5.0	1.9±	< 5.0	< 5.0	1.6±	< 5.0	< 50	1.9±
Iron, Total	**ug/L**	**NL**	**NL**	N/A	N/A	1,700	8,600	980	11,200	10,300	11,800	11,600	NA	NA
Iron, Dissolved	ug/L	N/A	N/A	N/A	N/A	48±	< 60	< 60	5,600	4,900	7,100	6,900	NA	NA
Lead, Total	**µg/L**	**14**	**26**	N/A	N/A	0.95±	38	1.7	< 1.0	< 1.0	< 1.0	< 1.0	< 50	< 1.0
Lead, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 50	< 2.0
Mercury, Total	**µg/L**	**1.2**	**2.2**	N/A	N/A	< 0.2	0.51	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Mercury, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 0.2	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Molybdenum, Total	**µg/L**	**NL**	**NL**	N/A	N/A	NA	50	NA	NA	97	NA	NA	430	400

Table 3 (continued)
Possum Point Dewatering Water Compared with VPDES Permit Limits for Internal Outfall 503

		VPDES Permit Limits				Pond E Rim Ditch			Pond E Well Points					
		Internal Outfall 503 - When Routed to 001/002 or 004				RMD-1	RMD-2	RMD-3	Well Discharge 1	Well Discharge 2	Well Discharge 3	Well Discharge 3 dup	PWCSA Sample	GAI Duplicate Sample
Parameters	**Units**	**Monthly Average**	**Daily Maximum**	**Minimum**	**Maximum**	**5/5/2015**	**5/6/2015**	**5/11/2015**	**5/11/2015**	**5/12/2015**	**5/13/2015**	**5/13/2015**	**7/30/2015**	**7/30/2015**
Molybdenum, Dissolved	µg/L	N/A	N/A	N/A	N/A	NA	46	NA	NA	80	NA	NA	370	430
Nickel, Total	**µg/L**	**24**	**44**	N/A	N/A	9.1	28	13	8.1	6.4	8.2	8.0	< 50	7.2
Nickel, Dissolved	µg/L	N/A	N/A	N/A	N/A	6.7	6.5	11	8.0	7.6	7.6	7.5	< 50	7.9
Selenium, Total	**µg/L**	**8.0**	**15**	N/A	N/A	9.3	40	8.8	0.84±	0.81±	1.3±	1.1±	< 50	9.2
Selenium, Dissolved	µg/L	N/A	N/A	N/A	N/A	8.5	25	10	1.8±	1.9±	< 5.0	1.7±	< 50	12
Silver, Total	**µg/L**	**2.2**	**4.0**	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	NA	NA
Silver, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	NA	NA
Thallium, Total	**µg/L**	**0.94**	**0.94**	N/A	N/A	0.61	1.4	0.68	< 0.50	< 0.50	< 0.50	< 0.50	NA	NA
Thallium, Dissolved	µg/L	N/A	N/A	N/A	N/A	0.50±	0.65±	0.61±	< 1.0	< 1.0	< 1.0	< 1.0	NA	NA
Vanadium, Total	**µg/L**	**NL**	**NL**	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	< 50	7.2
Vanadium, Dissolved	µg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	< 50	< 2.0
Zinc, Total	**µg/L**	**98**	**180**	N/A	N/A	7.3	66	13	26	16	16	16	< 50	6.9
Zinc, Dissolved	µg/L	N/A	N/A	N/A	N/A	8.4	5.4	8.5	12	190	11	12	< 50	36
Hardness, Total (as $CaCO_3$)	**mg/L**	**NL**	**NL**	N/A	N/A	193	246	231	463	401	417	415	NA	NA
Total Nitrogen	**mg/L**	N/A	N/A	N/A	N/A	NA	< 1.0	NA	NA	< 1.00	NA	NA	NA	NA
Total Kjeldahl Nitrogen	**mg/L**	N/A	N/A	N/A	N/A	NA	< 1.0	NA	NA	< 1.0	NA	NA	NA	NA
Nitrate+Nitrite (NO_3+NO_2), as N	**mg/L**	N/A	N/A	N/A	N/A	< 0.20 (4)	< 0.40	< 0.20 (4)	< 0.50 (4)	< 1.00	< 0.50 (4)	< 0.50 (4)	NA	NA
Ammonia, as N	**mg/L**	N/A	N/A	N/A	N/A	0.058±	0.062±	0.043±	0.306	0.322	0.287	0.282	NA	NA
Acute Toxicity – *C. dubia* (2)	**% NOEC**	N/A	N/A	**100%**	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acute Toxicity – *P. promelas* (2)	**% NOEC**	N/A	N/A	**100%**	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chronic Toxicity – *C. dubia* (3)	**TU_c**	N/A	N/A	N/A	**2.85**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chronic Toxicity – *P. promelas* (3)	**TU_c**	N/A	N/A	N/A	**2.85**	NA	NA	NA	NA	NA	NA	NA	NA	NA

Footnotes:

1 pH values measured in laboratory.
2 Reported as percent No Observed Effect Concentration (NOEC).
3 Reported as Chronic Toxicity Units (TU_C)
4 Value indicates nitrate (NO_3) only; nitrite was not measured.
5 Values preceded by "<" represent results not detected at the Reporting Detection Limit (RDL) and listed as < RDL.
6 Values with suffix "±" represent results with an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte.
7 NA = Not Analyzed
8 NL = No Limit
9 N/A = Not Applicable
10 VPDES Permit limits for comparison are for the discharge of Outfall 503 to Outfall 001/002.
11 Where Reporting Detection Limit (RDL) of dissolved metals exceeds total metals, the lab diluted the sample to obtain a result thus increasing the Limit of Quantitation (LOQ) and RDL by the factor of dilution.

Table 4
Possum Point Contact Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond E Contact Water
		Internal Outfall 503 - When Routed to 001/002 or 004				Pond E
		Monthly Average	Daily Maximum	Minimum	Maximum	5/5/2015
pH (1)	**S.U.**	N/A	N/A	**6.0**	**9.0**	7.89
Total Suspended Solids (TSS)	**mg/L**	**30**	**100**	N/A	N/A	39
Oil and Grease (O&G)	**mg/L**	**15**	**20**	N/A	N/A	< 2.0
Aluminum, Total	**ug/L**	**NL**	**NL**	N/A	N/A	1400
Aluminum, Dissolved	ug/L	N/A	N/A	N/A	N/A	110
Antimony, Total	**ug/L**	**1,300**	**1,300**	N/A	N/A	14
Antimony, Dissolved	ug/L	N/A	N/A	N/A	N/A	13
Arsenic, Total	**ug/L**	**240**	**440**	N/A	N/A	90
Arsenic, Dissolved	ug/L	N/A	N/A	N/A	N/A	80
Barium, Total	**ug/L**	**NL**	**NL**	N/A	N/A	210
Barium, Dissolved	ug/L	N/A	N/A	N/A	N/A	160
Beryllium, Total	**ug/L**	**NL**	**NL**	N/A	N/A	< 0.50
Beryllium, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 1.0
Boron, Total	**ug/L**	**NL**	**NL**	N/A	N/A	400
Boron, Dissolved	ug/L	N/A	N/A	N/A	N/A	400
Cadmium, Total	**ug/L**	**1.4**	**2.6**	N/A	N/A	< 0.50
Cadmium, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 1.0
Chloride	**µg/L**	**370,000**	**670,000**	N/A	N/A	72,000
Chromium III, Total	**ug/L**	**88**	**160**	N/A	N/A	< 10
Chromium III, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 10
Chromium VI, Total	**µg/L**	**17**	**32**	N/A	N/A	0.39
Chromium VI, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 0.25
Cobalt, Total	**µg/L**	**NL**	**NL**	N/A	N/A	< 2.5
Cobalt, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 5.0
Copper, Total	**µg/L**	**9.6**	**18**	N/A	N/A	< 6.2
Copper, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0
Iron, Total	**ug/L**	**NL**	**NL**	N/A	N/A	660
Iron, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 60
Lead, Total	**µg/L**	**14**	**26**	N/A	N/A	3.0
Lead, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0
Mercury, Total	**µg/L**	**1.2**	**2.2**	N/A	N/A	< 0.20

Table 4 (continued)
Possum Point Contact Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond E Contact Water
		Internal Outfall 503 - When Routed to 001/002 or 004				Pond E
		Monthly Average	Daily Maximum	Minimum	Maximum	5/5/2015
Mercury, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 0.20
Molybdenum, Total	**µg/L**	**NL**	**NL**	N/A	N/A	83
Molybdenum, Dissolved	µg/L	N/A	N/A	N/A	N/A	67
Nickel, Total	**µg/L**	**24**	**44**	N/A	N/A	14
Nickel, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0
Selenium, Total	**µg/L**	**8.0**	**15**	N/A	N/A	17
Selenium, Dissolved	µg/L	N/A	N/A	N/A	N/A	19
Silver, Total	**µg/L**	**2.2**	**4.0**	N/A	N/A	< 1.0
Silver, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0
Thallium, Total	**µg/L**	**0.94**	**0.94**	N/A	N/A	0.56
Thallium, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 1.0
Vanadium, Total	**µg/L**	**NL**	**NL**	N/A	N/A	N/A
Vanadium, Dissolved	µg/L	N/A	N/A	N/A	N/A	N/A
Zinc, Total	**µg/L**	**98**	**180**	N/A	N/A	9.1
Zinc, Dissolved	µg/L	N/A	N/A	N/A	N/A	7.8
Hardness, Total (as $CaCO_3$)	**mg/L**	**NL**	**NL**	N/A	N/A	193
Total Nitrogen	**mg/L**	N/A	N/A	N/A	N/A	< 1.00
Total Kjeldahl Nitrogen	**mg/L**	N/A	N/A	N/A	N/A	< 1.0
Nitrate+Nitrite (NO_3+NO_2), as N	**mg/L**	N/A	N/A	N/A	N/A	< 0.40
Ammonia, as N	**mg/L**	N/A	N/A	N/A	N/A	0.189
Acute Toxicity – *C. dubia* (2)	**% NOEC**	N/A	N/A	**100%**	N/A	N/A
Acute Toxicity – *P. promelas* (2)	**% NOEC**	N/A	N/A	**100%**	N/A	N/A
Chronic Toxicity – *C. dubia* (3)	**TU_c**	N/A	N/A	N/A	**2.85**	N/A
Chronic Toxicity – *P. promelas* (3)	**TU_c**	N/A	N/A	N/A	**2.85**	N/A

Footnotes:

1 pH values measured in the field.
2 Reported as percent No Observed Effect Concentration (NOEC).
3 Reported as Chronic Toxicity Units (TU_C)
4 Values preceded by "<" represent results not detected at the Reporting Detection Limit (RDL) and listed as < RDL.
5 Values with suffix "±" represent results with an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte.
6 NA = Not Analyzed
7 NL = No Limit
8 N/A = Not Applicable
9 VPDES Permit limits for comparison are for the discharge of Outfall 503 to Outfall 001/002.
10 Where Reporting Detection Limit (RDL) of dissolved metals exceeds total metals, the lab diluted the sample to obtain a result thus increasing the Limit of Quantitation (LOQ) and RDL by the factor of dilution.

Table 5
Identified Constituents for Which Treatment May Be Necessary in Order to Comply with VPDES Permit Limits

Parameter	VPDES Permit Limits for Discharge to Internal Outfall 503 When Routed to Outfall 001/002		Sampling Location	Observed Values
	Monthly Average	Daily Maximum		
Total Selenium (µg/L)	8.0	15	Ash Pond E Dewatering Water	8.8 - 40
			Ash Pond E Contact Water	17
Total Suspended Solids (mg/L)	30	100	Ash Pond E Dewatering Water	27 - 159
			Ash Pond E Contact Water	39
Total Nickel (µg/L)	24	44	Ash Pond E Dewatering Water	28
Total Thallium (µg/L)	0.94	0.94	Ash Pond E Dewatering Water	< 0.50 – 1.4
Total Arsenic (µg/L)	240	440	Ash Pond E Dewatering Water	51 – 1,200
Total Copper (µg/L)	9.6	18	Ash Pond E Dewatering Water	< 2.5 - 84
Total Lead (µg/L)	14	26	Ash Pond E Dewatering Water	< 1.0 - 38

FIGURES

GAI CAD FILE PATH: Z:\Energy\2015\C150132.00 - DOM - Possum Point PS CCB\Working Docs\Task 47 - Treatment Alternative_Concept Treatment Report\Drawings\C150132.00 - AERIAL Outfall Exhibit.dwg

DRAWING TITLE			DRAWN BY:	CHECKED BY:	APPROVED BY:
STATION OUTFALLS & TREATMENT FACILITIES			VASKOAJ	DEBARJD	QUINLSC
PROJECT		CLIENT	DWG TYPE:	SCALE:	ISSUE DATE:
POSSUM POINT POWER STATION **19000 POSSUM POINT ROAD** **DUMFRIES, PRINCE WILLIAM COUNTY** **VIRGINIA 22026**	gai consultants	**VIRGINIA ELECTRIC AND POWER COMPANY** **5000 DOMINION BOULEVARD** **GLEN ALLEN, VA 23060**		1" = 700'	03/01/2016
			SHEET NO.:	1 OF 1	
			GAI FILE NUMBER:		
			C150132.00 - AERIAL Outfall Exhibit		
			GAI DRAWING NUMBER:		
			FIGURE 1		

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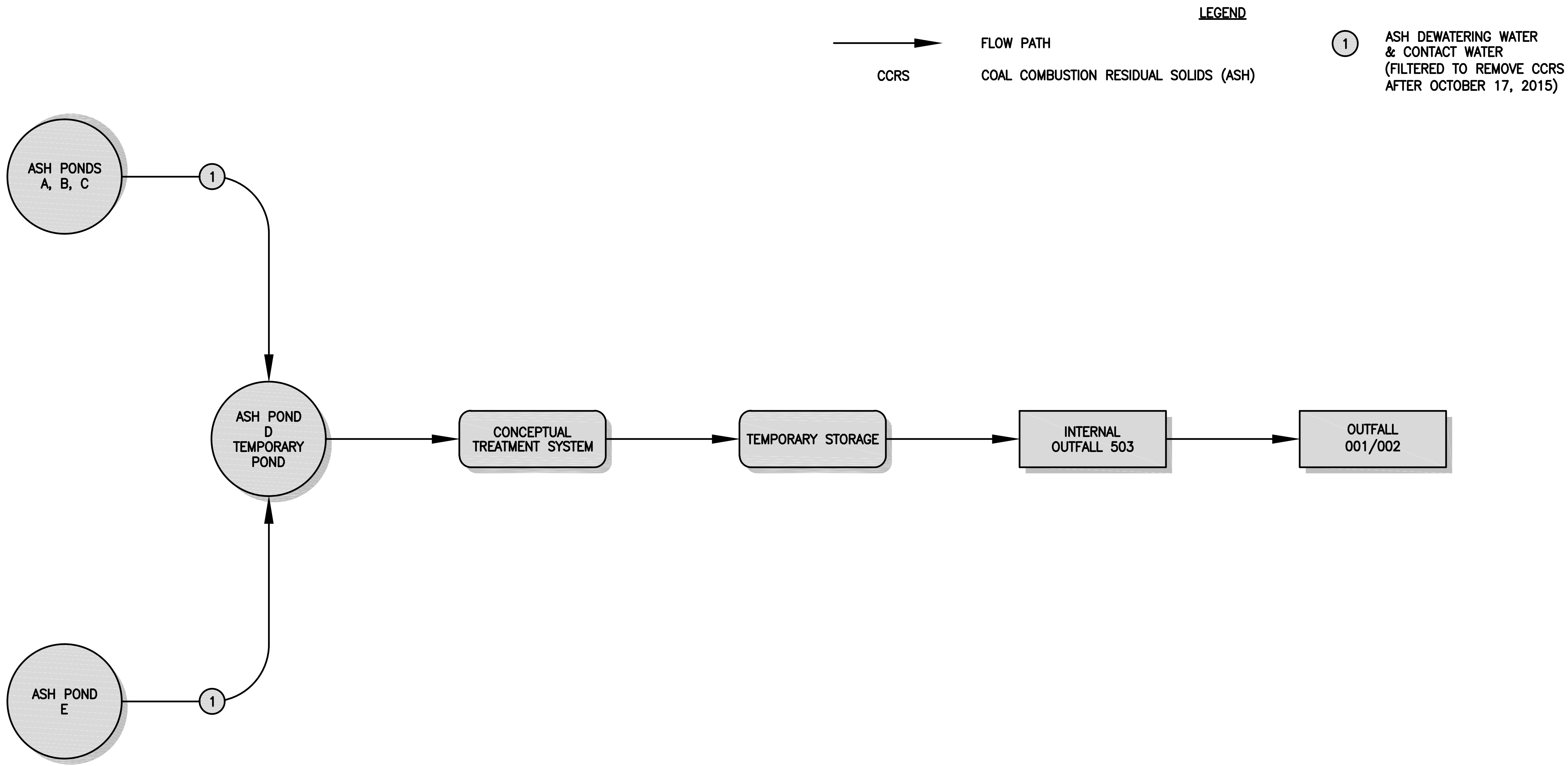
PLOTTED ON: 3/1/2016 9:07:14 PM PLOTTED BY: John DeBarbieri PLOT FILE: GAI.stb

00022382



NO.:	DATE:	DWN:	CHK:	APV:	DESCRIPTION:

REVISION RECORD

DRAWING TITLE

PROCESS FLOW DIAGRAM FOR INTERIM CONFIGURATION PHASE DURING CONSTRUCTION

PROJECT

POSSUM POINT POWER STATION
19000 POSSUM POINT ROAD
DUMFRIES, PRINCE WILLIAM COUNTY
VIRGINIA 22026

gai consultants

CLIENT

VIRGINIA ELECTRIC AND POWER COMPANY
5000 DOMINION BOULEVARD
GLEN ALLEN, VIRGINIA 23060

DRAWN BY:	CHECKED BY:	APPROVED BY:
VASKOAJ	DEBARJD	QUINLSC
REVISION	SCALE:	ISSUE DATE:
A/0	AS SHOWN	03/01/2016
	SHEET NO.: 1 OF 1	

GAI FILE NUMBER: **C150132-00-047-00-P-B2-002B**

GAI DRAWING NUMBER: **FIGURE 2**

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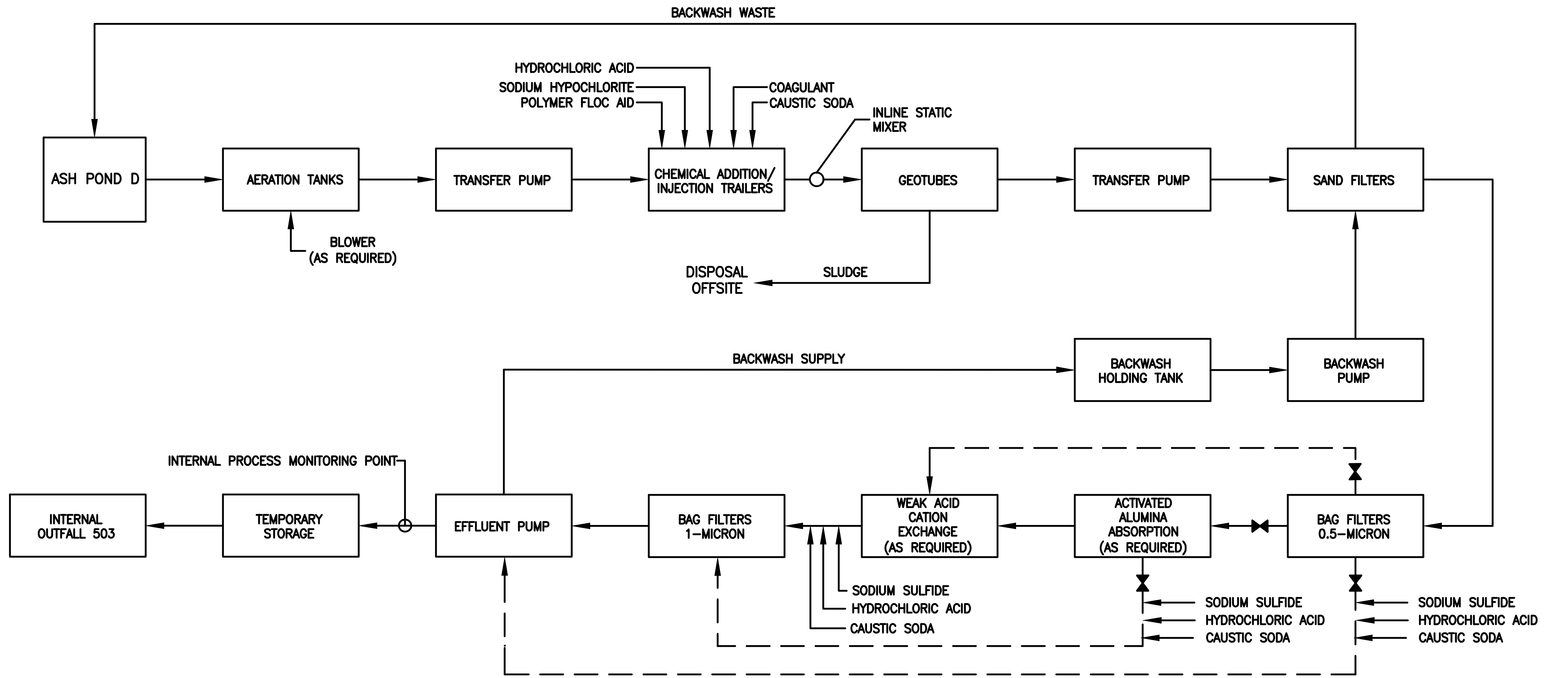
GAI CAD FILE PATH: Z:\Energy\2015\C150132.00 – DOM – Possum Point PS CCB\CAD\Production Drawings\PROCESS\C150132-00-047-00-P-B2-002B.dwg

PLOTTED ON: 3/1/2016 9:12:59 PM PLOTTED BY: John DeBarbieri PLOT FILE: GAI.stb



NOTES:

1. TREATMENT SYSTEM CONFIGURATION AS DESIGNED BY CARBONAIR.
2. BAG FILTER OPENING SIZES MAY BE CHANGED TO MEET TREATMENT NEEDS, AS REQUIRED.
3. SPENT GEOTUBES, FILTER BAGS, AND MEDIA SHALL BE DISPOSED IN A PERMITTED LANDFILL AND REPLACED, AS NEEDED.
4. PH ADJUSTMENT WITH HYDROCHLORIC ACID OR CAUSTIC SODA IS TO BE APPLIED, AS REQUIRED.

LEGEND

FLOW PATH

ALTERNATE FLOW PATH

VALVE

NO.:	DATE:	DWN:	CHK:	APV:	DESCRIPTION:

REVISION RECORD

DRAWING TITLE

TREATMENT PROCESS FOR INTERIM CONFIGURATION PHASE DURING CONSTRUCTION

PROJECT

POSSUM POINT POWER STATION
19000 POSSUM POINT ROAD
DUMFRIES, PRINCE WILLIAM COUNTY
VIRGINIA 22026

gai consultants

CLIENT

VIRGINIA ELECTRIC AND POWER COMPANY
5000 DOMINION BOULEVARD
GLEN ALLEN, VIRGINIA 23060

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VASKOAJ	DEBARJD	QUINLSC
REVISION	SCALE:	ISSUE DATE:
A/0	AS SHOWN	03/23/2016
	SHEET NO.: 1 OF 1	

GAI FILE NUMBER: **C150132-00-047-00-P-B2-002C**

GAI DRAWING NUMBER: **FIGURE 3**

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PLOTTED ON: 3/24/2016 4:17:07 PM PLOTTED BY: John DeBarbieri PLOT FILE: GAI.stb

DRAWING TITLE

SITE PLAN FOR INTERIM CONFIGURATION PHASE DURING CONSTRUCTION

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VASKOAJ	DEBARJD	QUINLSC
DWG TYPE:	SCALE:	ISSUE DATE:
	1" = 700'	03/01/2016

PROJECT

POSSUM POINT POWER STATION
19000 POSSUM POINT ROAD
DUMFRIES, PRINCE WILLIAM COUNTY
VIRGINIA 22026

gai consultants

CLIENT

VIRGINIA ELECTRIC AND POWER COMPANY
5000 DOMINION BOULEVARD
GLEN ALLEN, VIRGINIA 23060

SHEET NO.: 1 OF 1

GAI FILE NUMBER:
C150132.00-Site Plan

GAI DRAWING NUMBER:
FIGURE 4

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GAI CAD FILE PATH: Z:\Energy\2015\C150132.00 - DOM - Possum Point PS CCB\Working Docs\Task 47 - Treatment Alternative_Concept Treatment Report\Drawings\C150132.00-Site Plan.dwg

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APPENDIX A
Published Literature

AERATION UNIT PROCESS

- ITRC
- ITRC Mining Waste Public Page
- ITRC Mining Waste Guidance Home Page
- Decision Tree
- Technology Overviews
- Case Studies
- Regulatory Issues
- Stakeholder Values and Concerns
- Additional Resources
- Appendices
- Tutorial
- Contact Us
- Site Map

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Technology Overview as part of a Web-based Technical and Regulatory Guidance

Aeration Treatment Systems

1. Introduction

Click Here to view case study table at the end of this document.

The reduction of dissolved metals concentrations in mining-influenced water (MIW) is typically a key component in cleanup and management strategies at current and former mine sites. Aeration is an active water treatment process component used to enhance reduction of certain dissolved metals concentrations in MIW under specific geochemical conditions. Aeration is often applied in conjunction with acid-neutralizing agents (lime, limestone, caustic soda, soda ash), chemical oxidants (ozone, sodium hypochlorite, hydrogen peroxide, potassium permanganate), flocculants, filtration, and settling basins.

Aeration involves the mechanical introduction of oxygen into the MIW stream through a variety of techniques with the goal of oxidizing dissolved metals species into less soluble forms. Aeration uses gravity and/or mechanical devices to increase the concentration of dissolved oxygen in MIW, promoting oxidation of iron, manganese, arsenic, and other problematic metals species, increasing treatment effectiveness and efficiency, and decreasing remediation costs.

A variety of aeration technologies exist, ranging from simple gravity-driven cascading flumes to in-line systems that use Venturi-based jet pumps to inject oxygen into the MIW (INAP 2009). Aeration is commonly applied simultaneously with addition of lime and flocculant to increase pH, oxidize metals species, and precipitate metal hydroxides that are then treated through settlement, filtering, or other processes.

2. Applicability

Aeration is applicable to the following situations:

- MIW discharge containing elevated dissolved metals concentrations, with low natural dissolved oxygen
- wide variety of sites suitable for active treatment technologies
- wide range of flow conditions
- used in conjunction with other metals and neutralization treatment technologies

Aeration is most commonly used for the treatment of MIW containing levels of dissolved metals that exceed regulatory or risk-based water quality standards. MIW often has low pH and low dissolved oxygen content and may contain elevated carbon dioxide (CO_2). In addition MIW commonly contains elevated levels of iron (Fe^{2+}), manganese (Mn^{2+}), and other metals that are mobile as dissolved constituents. The introduction of dissolved oxygen through aeration results in oxidation of the metals species into less soluble forms. Where elevated levels of CO_2 are present in MIW, aeration reduces the dissolved CO_2 content, thereby increasing the pH.

Aeration techniques can be engineered to treat a wide range of flow conditions, including sites with very high flow rates and sites with highly variable flow rates. The website at www.gardguide.com/index.php/Aeration_systems_for_treating_CMD (INAP 2009) provides examples of various techniques for application of aeration with and without other treatment.

3. Advantages

The advantages of aeration include the following:

- simplicity and effectiveness of the fundamental geochemical process
- application flexibility
- the use of air as the treatment reagent
- wide range of site conditions
- wide range of flow conditions

Oxidation reactions are straightforward and readily occur when oxygen is introduced into low-oxygen MIW containing reduced metals species. Mechanical aeration is an effective and relatively inexpensive method for introducing oxygen. Depending on the contaminants being addressed, pH adjustment may be necessary in addition to aeration to achieve the desired oxidation reaction.

Aeration technologies can be adapted to a wide range of site conditions, making them suitable for remote sites as well as active and/or easily accessible mine sites. Aeration most commonly uses atmospheric air as the treatment reagent, avoiding the permitting, management, handling, and disposal issues that may apply to other chemical reagents.

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AERATION UNIT PROCESS

4. Limitations

Aeration introduces oxygen into MIW and is, therefore, applicable to sites with MIW discharge containing elevated, dissolved, reduced metals species concentrations with low natural dissolved oxygen. Sites where MIW has relatively high oxygen content will not benefit appreciably from aeration technologies. Aeration has use as a sole remediation technology in limited situations, but is much more commonly applied in conjunction with other technologies.

5. Performance

No performance data specific to aeration technologies were identified for this technology overview. Aeration is sometimes applied alone but is most commonly applied in conjunction with other treatment technologies to achieve regulatory or risk-based water quality standards. An example system described by EPA (2004) is the In-Line Aeration and Neutralization System, which uses a jet pump or eductor to entrain the air and alkaline chemical by Venturi action and a static mixer. Sodium hydroxide or sodium carbonate is added to the MIW with aeration to create flocculation. The flocculant is directed through a static mixer, to a clarifier, and then to settling ponds.

At the Leviathan Mine Case Study in California, a proprietary technology, Rotating Cylinder Treatment System (RCTS), was used to treat MIW drainage overflows from containment ponds on site during high spring runoff conditions at a rate of 30–300 gallons per minute. The MIW was acidic and contained high concentrations of sulfate and metals, including aluminum, arsenic, cadmium, copper, iron, manganese, nickel, selenium, and zinc. The process involved the use of aeration and lime neutralization to oxidize and precipitate the metals and treat 3 million to 20 million gallons of MIW annually.

The report for the RCTS indicated results for delivery of 9 pounds of oxygen per horsepower-hour and that mechanical surface aeration and submerged turbine aeration deliver 2–3.5 pounds of oxygen per horsepower-hour. The system treated 28 million liters over 85 days at average rates of several hundred liters per minute and a maximum rate of 2800 liters per minute (Tsukamoto n.d.).

As an active treatment method, aeration requires some level of ongoing operations, maintenance, and monitoring and a source of energy (gravity or electrical power) using infrastructure and engineered systems (INAP 2009). However, the level of operations and maintenance and power consumption covers a wide range. Simple gravity-driven flume systems may require infrequent maintenance and no electrical power. In-line systems can be designed to operate using excess systemic water pressure from an existing treatment plant. Otherwise, they can be designed to require little additional electrical power. As such, aeration systems are applicable to a wide range of mine site locations, ranging from remote sites with limited or no power, to active mining operations with comprehensive power infrastructure and labor resources.

6. Costs

No cost information specific to aeration technologies was identified for this technology overview. Aeration costs are primarily associated with capital costs for system design and construction and energy costs and sludge management during operation. Gusek and Figueroa (2009) noted that costs for acid-neutralization technologies, which may be applied in conjunction with aeration, are on the order of several dollars per thousand gallons of treated water. Treatment chemicals can account for one- to two-thirds of the treatment costs. The use of aeration may reduce treatment costs, since the quantity of treatment chemicals is reduced due to the technology using atmospheric air.

7. Regulatory Considerations

Aeration technologies do not add unique additional regulatory considerations than would be otherwise applicable to other MIW technologies. Because aeration typically uses atmospheric air as the reagent, there are no reagent permitting, management, handling, and disposal issues that may apply to other chemical reagents.

8. Stakeholder Considerations

Aeration technologies are not expected to add unique additional stakeholder considerations that would not be otherwise applicable to the other MIW technologies being applied at the site.

9. Lessons Learned

Aeration technologies can be a cost-effective addition to MIW treatment to enhance oxidation and solubility reduction for metals species in MIW. The addition of aeration to other MIW technologies can reduce chemical reagent use and costs. Developments in aeration technology, such as the RCTS, can improve oxygenating efficiency, thus reducing energy costs.

10. Case Studies

Table 10-1. Case study including aeration technology

Leviathan Mine, CA

11. References

EPA (U.S. Environmental Protection Agency). 2004. "Appendix C. Current Information on Mine Waste Treatment Technologies," in *Abandoned Mine Lands Team Reference Notebook*. www.epa.gov/aml/tech/appenc.pdf.

Gusek, J. J., and L. A. Figueroa, eds. 2009. *Mitigation of Metal Mining Influenced Water*. Littleton, CO: Society for Mining, Metallurgy, and Exploration.

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AERATION UNIT PROCESS

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FLOCCULATION/SEDIMENTATION UNIT PROCESSES

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Technical Bulletin

Drinking Water Treatment with Ferric Chloride

Before the 1800's finding sanitary drinking water in the cities of the world was a risky enterprise. The separation of drinking water and human waste was not assured and illness and death due to water borne diseases was very common. In the mid-1800's the connection was made between water purity and public health. Once that connection was made, a concerted effort began to develop water treatment processes that would guaranty the safety of the populace. Over the next century, progress in water treatment methods in the United States, Canada and Northern Europe, came to produce drinking water unequalled in quality and it was reasonable that these largely successful methods should become standardized.

In 1974, the Safe Drinking Water Act was passed by the United States Congress. In 1986 amendments to this act were passed that have radically changed the face of drinking water standards and the processes used to produce potable water in the United States. Water producers soon discovered that the old "tried and true" treatment processes were now inadequate to meet today's requirements. These new requirements made it necessary to re-evaluate the total water plant operation. One of the outcomes of this re-evaluation has been a focus on determining the correct coagulant to meet these new requirements. Ferric chloride has often been central to this discussion.

Ferric chloride is not new to the drinking water treatment industry and has been commercially available in the United States since the1930's. However, it has only been in the past 15 years that a trend towards increased acceptance of ferric chloride for drinking water treatment has evolved. This is due in large part to significant improvements in product economics, quality and availability. Since 1986 there has been a ground swell in interest in ferric chloride not only for the treatment of turbidity but additionally for the removal of color, natural organic materials and arsenic from raw waters. California Water Technologies has been instrumental in helping Water Treatment Plants understand the extensive capabilities of this coagulant.

Ferric chloride is an interesting compound. It is produced as a solution from the oxidation of ferrous chloride with chlorine and it has the unusual distinction of being one of the purest and most concentrated forms of iron commercially available for water treatment. However, what is truly unusual is its chemistry is that ferric chloride not only functions as a reactant to remove water impurities but it also functions as both a coagulant and a flocculant. Its versatility is enormous.

The reactions of ferric chloride in water include an ability to form precipitates with hydrogen sulfide (H_2S), phosphate (PO_4), arsenic as arsenate (AsO_4) and hydroxide alkalinity (OH).

In drinking water treatment, however, understanding ferric chloride's reaction with hydroxide alkalinity is the primary key to understanding its effectiveness as a coagulant/ flocculant.

Ferric chloride reacts in water with hydroxide alkalinity to form various hydrolysis products that incorporate $Fe(OH)_3$. These compounds possess high cationic charge which allows them to neutralize the electrostatic charges found on colloidal compounds and also to bind to negatively charged particles, including the ferric hydroxide itself. This ability to bind to itself is the mechanism for the formation of floc aggregates and the basis for ferric chloride's flocculation abilities.

The hydrolysis products from ferric chloride, nominally ferric hydroxide, are different from those of sulfate based ferric sulfate and aluminum sulfate (alum). The aggregates or floc particles of ferric hydroxide are physically more discrete and dense and have a higher cationic charge density. In contrast, the floc aggregates of ferric sulfate and aluminum sulfate tend to be less discrete and "fluffy" or cloud like, this apparently due to differences in the types of bonding of the hydrolysis products. These differences translate into characteristics and abilities for ferric chloride that set it far apart from the sulfate based coagulants. In typical plant situations one can expect to use about 30% less ferric chloride than aluminum sulfate (on a dry weight basis) to achieve similar results.

Ferric Chloride forms a more discrete and dense floc that promotes faster sedimentation in general and specifically, better sedimentation in cold water. This dense floc has more available cationic charge that allows higher reactivity with colloidal solids. The high ratio of cationic charge to total mass also makes the ferric chloride hydrolysis products more reactive and adsorptive with emulsified and semi-emulsified organic matter; such as oils, fats, and other natural and synthetic organic matter. This would explain the ability of ferric chloride to remove TOC and other disinfection by product precursors (DBP's).

The high density of the ferric hydroxide floc leads to another important benefit for the treatment plant. The settled sludge volume of the ferric (chloride) hydroxide ranges typically from 1/3 to 2/3 that of sulfate based coagulants. Additionally, the sludge developed through the use of ferric chloride is generally much more dewaterable. So, although the ferric hydroxide molecule itself is heavier than the aluminum hydroxide molecule, this does not translate into more sludge to be disposed of. Instead, because sludge is disposed of on a wet basis rather than on a dry basis, the use of ferric chloride produces fewer wet tons of sludge and yields significant solids handling and disposal savings.

One of the other characteristics of ferric chloride is its ability to form floc over a very wide pH range as is demonstrated in the accompanying charts. The charts also show the very low solubility of ferric hydroxide compared to aluminum hydroxide. The combination of these properties allow ferric chloride to function over a very wide pH range with little fear of carry over into down stream processes due to post precipitation. This ends up being very important for operations looking to flocculate at higher pH's and alkalinity's while controlling

corrosivity factors in the water. Additionally, the low end of the pH range becomes especially important to enhanced coagulation processes.
Although there is little formal data regarding the use of ferric chloride as a filtration aid there is much operational data that speaks to its ability to greatly enhance turbidity removal with both slow and rapid sand filter filtration. Additionally there are more recent reports that speak to the use of iron coated sand in the removal of manganese.

Potable Water Treatment Applications

- Turbidity removal
- Enhanced Coagulation
- NOM, DBP precursor removal
- Color removal
- Arsenic reduction
- Softening Solids Sedimentation Aid
- Filtration Aid

Summary of benefits

- Very effective in the removal of high and low turbidity
- Extremely effective in removal of color, NOM and DBP precursors
- Works over a wide pH range
- Lower dosage requirements than other sulfate based coagulants
- Low cost
- Makes a heavier floc that settles faster and works better in cold water
- Produces higher sludge concentrations **=** Lower sludge disposal costs
- High iron content sludge is not considered hazardous to the environment and is compatible and beneficial with many land application residuals programs

Handling Ferric Chloride- **Read and understand the Ferric Chloride Material Safety Data Sheet**

It is extremely important that we handle Ferric Chloride and all chemicals with respect and in a safe manner. Always wear personal protective safety equipment and practice good housekeeping. For more information contact your PVS Technologies representative or resource the material safety data sheet.

Treatment Methods

Our experience has taught us that each water treatment facility must be approached individually. Differences in raw quality, treatment requirements, facility capabilities and staff expertise require solutions to treatment that are custom designed for the facility. Contact your California Water Technologies representative for knowledgeable assistance in developing solid solutions to your treatment needs.

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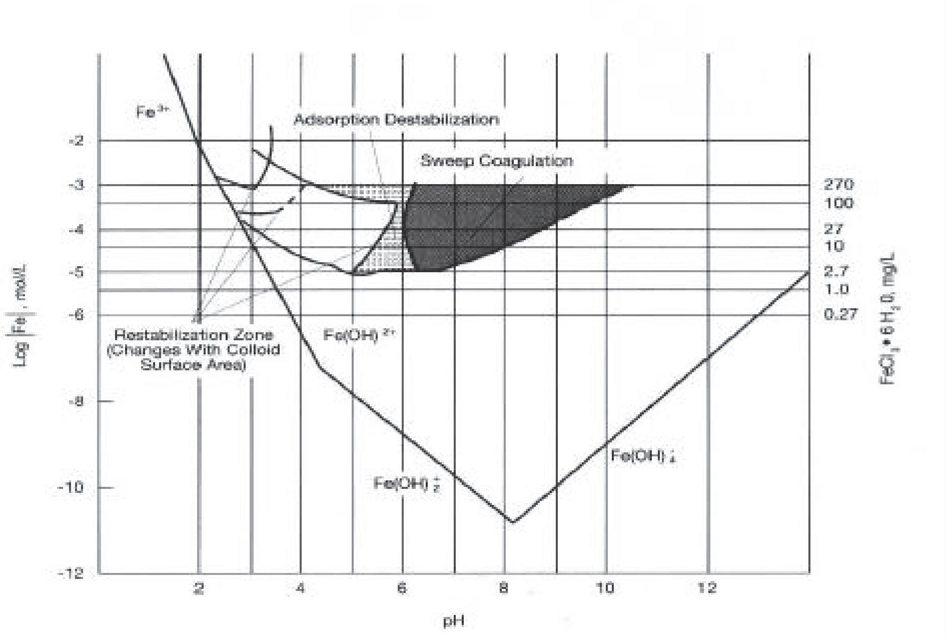
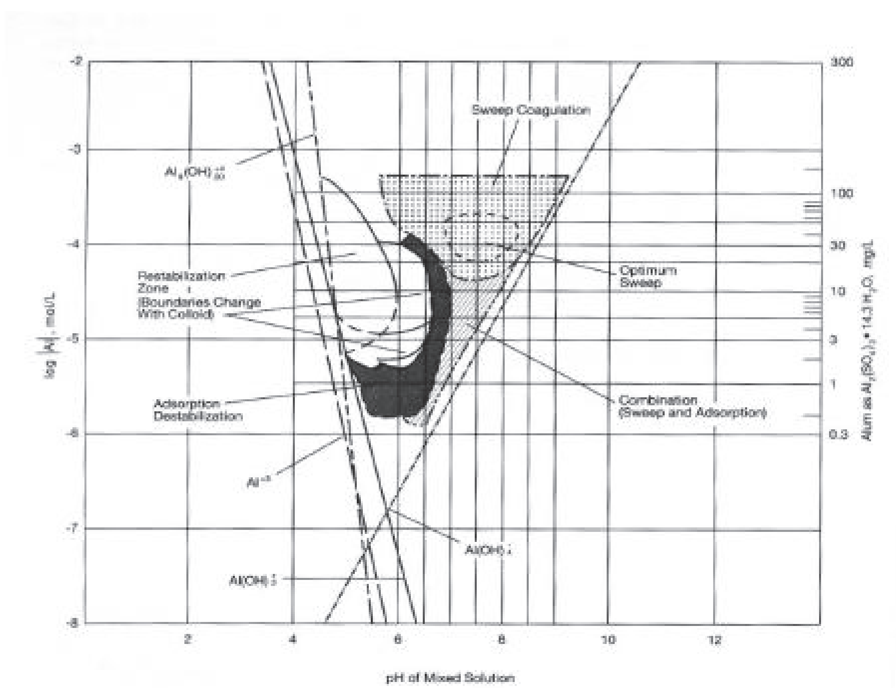
Ferric Chloride Solubility Chart

Source: Johnson P.N. & Amirtharajah A. 1983. *Ferric Chloride and Alum as Single and Dual Coagualants* Jour. AWWA, 75:5:232.



Aluminum Sulfate Solubility Chart

Source: Amirtharajah A. & Mills, K.M. 1992 *Rapid-Mix Design for Mechanisms of Alum Coagulation* Jour. AWWA, 74:4:210.



FLOCCULATION, FILTRATION, ACTIVATED ALUMINA, AND ION EXCHANGE UNIT PROCESSES

Water Treatment Technology Feasibility Support Document for Chemical Contaminants; In Support of EPA Six-Year Review of National Primary Drinking Water Regulations

00022394

FLOCCULATION, FILTRATION, ACTIVATED ALUMINA, ION EXCHANGE UNIT PROCESSES

A. Beryllium

Recent EPA occurrence analyses estimated beryllium occurrence in public water systems based on a sampling of 16 States (USEPA, 2003b). Based on these analyses, EPA estimates indicate a total of 15 water systems (credible interval of 7 to 24)[1] within these States may have a system mean concentration exceeding the threshold of 0.004 milligrams per liter (mg/L), (*i.e.*, the current MCL for beryllium). Additional occurrence estimates may be found in the above-cited 2003 EPA report.

The current BATs for beryllium removal include activated alumina, ion exchange, lime softening, coagulation/filtration, and reverse osmosis (USEPA, 1990b; USEPA, 1990c; 57 FR 31776 at 31809, July 17, 1992 (USEPA,1992)). Compliance technologies for small systems include these same five BATs, plus point-of-use (POU)-reverse osmosis, POU-ion exchange for small systems (USEPA, 1998b). Removal efficiencies for the above-cited BATs range from 80 to 99 percent. Treatment technologies were discussed by EPA in its technical support documentation on beryllium (USEPA, 1990c). If a treatment plant were to require upgrading, additional ion exchange contact units may be added, POU treatment installed, or a modification to precipitative processes added, as appropriate. The Agency's current assessment is that treatment technology would not pose a limitation, should EPA pursue a revision to this standard.

The current BATs and small system compliance technology for beryllium also apply to other contaminants. These treatment technologies have other beneficial effects (e.g., reduction of hardness or other common impurities) in addition to beryllium removal. If EPA were to consider a higher MCL, the Agency does not know how many of these public water systems currently treating to comply with the current MCL of 0.004 mg/L would be likely to discontinue any treatment that is already in place.

B. Chromium (Total)

1. <u>Treatment technology</u>

Recent EPA occurrence analyses indicate chromium occurrence in public water systems based on a sampling of 16 States (USEPA, 2003b). Based on these analyses, EPA estimates indicate that one water system (credible interval of 0 to 3) within these States may have a system mean concentration exceeding the threshold of 0.1 mg/L, the current MCL for total chromium. In addition, EPA estimates indicate a total of seven systems (credible interval of 3 to13) within these States may exceed the threshold of 0.05 mg/L. Additional occurrence estimates may be found in the above-cited 2003 EPA report.

In publishing the 1989 proposed and 1991 final chromium standard (54 FR 22062 at 22105, May 22, 1989 (USEPA, 1989); 56 FR 3526 at 3552, January 30, 1991 (USEPA, 1991a)) the Agency discussed BATs which include:

- Ion exchange: 80 to 96 percent efficiency;

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[1] "Credible intervals" are generated to quantify the uncertainty around each estimated probability in the Bayesian analysis of the occurrence data. For further explanation of credible intervals and the Bayesian analysis, please see *Occurrence Estimation Methodology and Occurrence Findings Report for the Six-Year Review of Existing National Primary Drinking Water Regulations* (USEPA, 2003b).

- Lime softening for chromium III only: 72 to 99 percent efficiency;
- Coagulation/filtration: 90 to 99 percent efficiency; and
- Reverse osmosis: 82 to 97 percent efficiency.

Due to the ionic properties of the two chromium species in water, chromium III and chromium VI, there is a differentiation in BAT specification which may affect treatment selection. Chromium III and chromium VI exist in water in cationic and anionic valence states, respectively. Lime softening treatment is excluded as a BAT for anionic chromium VI. Regarding the coagulation/filtration option, the choice of coagulant will impact chromium III and chromium VI removal. Ferric sulfate and alum are effective for removal of chromium III, while ferrous sulfate is effective for removal of chromium VI. Regarding ion exchange, a cation exchange resin is required for chromium III, while an anionic resin is required for chromium VI. Therefore, prior to use (or modification) of lime softening, ion exchange, or coagulation/filtration treatment, a public water system should determine concentrations and proportions of species of chromium to select proper media or chemical aid.

The 1996 SDWA Amendments require EPA to determine small system technologies for compliance purposes, (*i.e.*, technology designated as suitable for systems serving 25 to 10,000 persons). In 1998, EPA listed the following compliance technologies for small systems: ion exchange, lime softening (chromium III only), coagulation/filtration, reverse osmosis, POU-reverse osmosis, and POU-ion exchange (USEPA, 1998b).

Due to the high efficiencies of chromium removal by the above technologies, EPA believes that existing BATs would be adequate in meeting a revised standard (if the standard were lowered). Thus, the Agency's current assessment is that treatment technology would not pose a limitation should EPA pursue a revision to the chromium standard.

Due to recent interest by the State of California in setting a drinking water standard for chromium VI (the more toxic form of chromium), that State and others have initiated treatment studies to determine the efficacy of treatment technologies in removal of chromium VI to levels that are lower than the federal standard for total chromium. Newer treatments of interest include an iron-based absorptive filter medium, granular ferric hydroxide (GFH), a technology that has been piloted for arsenic removal at California water systems, and in the United Kingdom. Also, a treatment to reduce low levels of chromium VI to chromium III in drinking water by addition of the chemical stannous chlorine ($SnCl_2$) is currently under investigation at a water system in Glendale, California. EPA will monitor treatment studies to determine acceptability for use in removal of chromium from drinking water.

2. Additional information

Of additional interest to EPA is the likelihood that disinfection treatment, including chlorination, plays a role in transforming, by oxidation, chromium III to chromium VI in water. The EPA *Manual of Treatment Techniques for Meeting the Interim Primary Drinking Water Regulations* (USEPA, 1977) and the EPA *Occurrence and Exposure Assessment for Chromium in Public Drinking Water Supplies* (USEPA, 1990a) discussed effects of chlorination on chromium III in raw water (spiked) and in finished water. EPA found that time of contact, pH and other factors influence oxidation of the species. In addition, a Health Canada criteria summary on chromium in drinking water also indicated uncertainty with respect to whether post-treatment with chlorine, affecting conversion of residual chromium III to chromium VI, may

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The 1986 final fluoride regulation set "best technologies generally available" (BTGAs) as activated alumina and reverse osmosis. BTGA was defined prior to the SDWA Amendments of 1986, based upon measures of technological efficiency and economic accessibility (*i.e.*, "reasonably affordable by regional and large metropolitan public water systems"). The following factors were considered in determination of BTGA: high removal rate; wide applicability; compatibility with other treatments; and ability to achieve compliance for all water in the public water system (51 FR 11396 at 11398, April 2, 1986 (USEPA, 1986)). These requirements are comparable with current SDWA requirements for BAT determination.

In addition, the 1996 SDWA amendments require EPA to determine small system technologies for compliance purposes, (*i.e.*, technology designated as suitable for systems serving 25 to 10,000 persons). In 1998, EPA listed small system compliance technologies, including both centralized activated alumina and reverse osmosis treatment, as well as POU-reverse osmosis, for removal of fluoride in drinking water (USEPA, 1998b).

The Agency does not believe that the "BTGA" or small systems compliance technologies pose a problem. In addition, should a revision to the designation of "BATs" for this contaminant be considered by EPA, in lieu of the originally specified "BTGA" designation, this would represent a minor revision to the NPDWR (see 40 CFR 141.62 for MCLs for Inorganic Contaminants; and 40 CFR 142.61, which specifies variance technologies for fluoride).

Previously published research and EPA technologies and costs documents (USEPA, 1985b) on these technologies indicate that, due to high efficiencies of removal, the above-cited treatment technologies would not be a limiting factor in setting a lower fluoride MCL. Efficiencies of removal range from 85 to 95 percent, depending upon treatment system design. Thus, the Agency's current assessment is that treatment technology would not pose a limitation should EPA pursue a revision to the fluoride standard.

Both activated alumina and reverse osmosis treatment remove arsenic *and* fluoride among other impurities. Using activated alumina treatment, optimum removals for both contaminants may occur in a similar range of pH 5.5 to pH 6 (USEPA, 1985b; USEPA, 2000b). However, because arsenic V and silica are preferentially adsorbed by activated alumina media, effectiveness of activated alumina where arsenic and fluoride co-occur may require some investigation. Another activated alumina treatment shortcoming, discussed further below, is the operational difficulty of adding pH adjustment for optimizing removal efficiency (*i.e.*, adjusting pH prior to and after treatment). For some small systems, treatment may be limited to using "*natural*" pH levels (*i.e.*, unadjusted) thus sacrificing some removal efficiency. However, this application for fluoride removal is not documented.

The Agency discussed technical issues related to activated alumina technology in the above-cited fluoride final rule, including waste generation and disposal. More recent EPA publications have also examined the operation of activated alumina technology and perceived difficulties posed by chemical handling by small systems, (*i.e.*, for pH adjustment and for regeneration of the media), as well as the alternatives to regeneration of activated alumina media. In the case of arsenic treatment, the Agency recommended against the regeneration of activated alumina media at both small centralized treatment and POU applications, due in part to the difficulty of disposing of brine wastes. EPA instead assumed that spent activated alumina media would be disposed of directly at a landfill on a "throw-away" basis and that, based upon arsenic toxicity characteristic leaching procedure (TCLP) testing, this waste would not be deemed

Heptachlor is a moderately adsorbed organic contaminant (54 FR 22062 at 22105, May 22, 1989 (USEPA, 1989); 56 FR 3526 at 3552, January 30, 1991 (USEPA, 1991a)). EPA's preliminary assessment is that treatment technology is not anticipated to pose a limitation should the Agency consider revising the current MCL.

3. Heptachlor Epoxide

The BAT for heptachlor epoxide is GAC (56 FR 3526 at 3552, January 30, 1991 (USEPA, 1991a)), and compliance technologies for small systems include GAC, PAC, and POU-GAC (USEPA, 1998b). Since the results of the analytical methods feasibility review indicate that it may be possible to recalculate the PQL for heptachlor epoxide, EPA has reviewed treatment feasibility to determine if it is likely to become an issue if EPA were to revise the MCL. Treatment is not known to be a limiting concern for the current MCL.

Heptachlor epoxide is a strongly adsorbed organic contaminant, generally attributed to a low carbon usage rate (54 FR 22062 at 22105, May 22, 1989 (USEPA, 1989); 56 FR 3526 at 3552, January 30, 1991 (USEPA, 1991a)). Based on this information, EPA's current assessment is that treatment technology is not anticipated to pose a limitation should the Agency consider revising the current MCL.

4. Hexachlorobenzene

The BAT for hexachlorobenzene is GAC (57 FR 31776 at 31809, July 17, 1992 (USEPA, 1992)), and compliance technologies for small systems include GAC, PAC, and POU-GAC (USEPA, 1998b). Since the results of the analytical methods feasibility review indicate that it may be possible to recalculate the PQL for hexachlorobenzene, EPA has reviewed treatment feasibility to determine if it is likely to become an issue if EPA were to revise the MCL. Treatment is not known to be a limiting concern for the current MCL.

Since hexachlorobenzene is a moderately adsorbed contaminant, EPA's current assessment is that treatment technology is not anticipated to pose a limitation should the Agency consider revising the current MCL.

5. Thallium

BATs for thallium include activated alumina and ion exchange (57 FR 31776 at 31809, July 17, 1992 (USEPA, 1992)). EPA also listed small systems compliance technologies for this contaminant as activated alumina, ion exchange, POU-ion exchange (USEPA, 1998b). Since the results of the analytical methods feasibility review indicate that it may be possible to recalculate the PQL for thallium, EPA has reviewed treatment feasibility to determine if it is likely to become an issue if EPA were to revise the MCL. Treatment is not known to be a limiting concern for the current MCL.

According to technical information provided previously by EPA for thallium, competing ions in water may affect treatment run lengths (USEPA, 1998b). Assuming reasonable engineering practices, high removals of this contaminant are feasible. Removals may be expected to be greater than 90 percent using cation exchange systems, and greater than 95 percent using activated alumina treatment (55 FR 30370 at 30416, July 25, 1990 (USEPA, 1990d)). Based on this information, EPA's current assessment is that treatment technology is not anticipated to pose a limitation should the Agency consider revising the current MCL.

Other McGraw-Hill Reference Books of Interest

AMERICAN WATER WORKS ASSOCIATION • *Water Treatment Plant Design*
AVALLONE AND BAUMEISTER • *Marks' Standard Handbook for Mechanical Engineers*
BRATER • *Handbook of Hydraulics*
CONSIDINE • *Process Instruments and Controls Handbook*
CORBITT • *Standard Handbook of Environmental Engineering*
DEAN • *Lange's Handbook of Chemistry*
FREEMAN • *Standard Handbook of Hazardous Waste Treatment and Disposal*
GAYLORD AND GAYLORD • *Structural Engineering Handbook*
GRIGG • *Water Resources Planning*
HARRIS • *Handbook of Noise Control*
HICKS • *Standard Handbook of Engineering Calculations*
KARASSIK ET AL. • *Pump Handbook*
MERRITT • *Standard Handbook for Civil Engineers*
MILLER • *Flow Measurement Engineering Handbook*
NALCO • *The Nalco Water Handbook*
PERRY AND GREEN • *Perry's Chemical Engineers' Handbook*
ROSA • *Water Treatment Specification Manual*
ROSALER AND RICE • *Standard Handbook of Plant Engineering*
SCHWEITZER • *Handbook of Separation Techniques for Chemical Engineers*
SHINSKEY • *Process Control Systems*
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ACTIVATED ALUMINA ADSORPTION UNIT PROCESS

Water Quality and Treatment

A Handbook of Community Water Supplies

American Water Works Association

Frederick W. Pontius, *Technical Editor*

Fourth Edition

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ACTIVATED ALUMINA ADSORPTION UNIT PROCESS

TABLE 3.1 General Effectiveness of Water Treatment Processes for Contaminant Removal[1–45]

Contaminant categories	Aeration and stripping (Chap. 5)	Coagulation processes, sedimentation, filtration (Chaps. 6,7,8)	Lime softening (Chap. 10)	Ion exchange: Anion (Chap. 9)	Ion exchange: Cation (Chap. 9)	Membrane processes: Reverse osmosis (Chap. 11)	Membrane processes: Ultra filtration (Chap. 11)	Membrane processes: Electrodialysis (Chap. 11)	Chemical oxidation, disinfection (Chaps. 12,14)	Adsorption: GAC (Chap. 13)	Adsorption: PAC (Chap. 13)	Adsorption: Activated alumina (Chap. 9)
A. Primary contaminants												
1. Microbial and turbidity												
Total coliforms	P	G–E	G–E	P	P	E	E	—	E	F	P	P–F
Giardia lamblia	P	G–E	G–E	P	P	E	E	—	E	F	P	P–F
Viruses	P	G–E	G–E	P	P	E	E	—	E	F	P	P–F
Legionella	P	G–E	G–E	P	P	E	E	—	E	P	P	P–F
Turbidity	P	E	G	F	F	E	E	—	P	F	P	P–F
2. Inorganics												
Arsenic (+ 3)	P	F–G	F–G	G–E	P	F–G	—	F–G	P	F–G	P–F	G–E
Arsenic (+ 5)	P	G–E	G–E	G–E	P	G–E	—	G–E	P	F–G	P–F	E
Asbestos	P	G–E	—	—	—	—	—	—	P	—	—	—
Barium	P	P–F	G–E	P	E	E	—	G–E	P	P	P	P
Cadmium	P	G–E	E	P	E	E	—	E	P	P–F	P	P
Chromium (+ 3)	P	G–E	G–E	P	E	E	—	E	F	F–G	F	P
Chromium (+ 6)	P	P	P	E	P	G–E	—	G–E	P	F–G	F	P
Cyanide	P	—	—	—	—	G	—	G	E	—	—	—
Fluoride	P	F–G	P–F	P–F	P	E	—	E	P	G–E	P	E
Lead	P	E	E	P	F–G	E	—	E	P	F–G	P–F	P
Mercury (inorganic)	P	F–G	F–G	P	F–G	F–G	—	F–G	P	F–G	F	P
Nickel	P	F–G	E	P	E	E	—	E	P	F–G	P–F	P
Nitrate	P	P	P	G–E	P	G	—	G	P	P	P	P
Nitrite	F	P	P	G–E	P	G	—	G	G–E	P	P	P
Radium (226 and 228)	P	P–F	G–E	P	E	E	—	G–E	P	P–F	P	P–F
Selenium (+ 6)	P	P	P	G–E	P	E	—	E	P	P	P	G–E
Selenium (+ 4)	P	F–G	F	G–E	P	E	—	E	P	P	P	G–E
3. Organics												
VOCs	G–E	P	P–F	P	P	F–E	F–E	F–E	P–G	F–E	P–G	P
SOCs	P–F	P–G	P–F	P	P	F–E	F–E	F–E	P–G	F–E	P–E	P–G
Pesticides	P–F	P–G	P–F	P	P	F–E	F–E	F–E	P–G	G–E	G–E	P–G
THMs	G–E	P	P	P	P	F–G	F–G	F–G	P–G	F–E	P–F	P
THM precursors	P	F–G	P–F	F–G	—	G–E	F–E	G–E	F–G	F–E	P–F	P–F
B. Secondary contaminants												
Hardness	P	P	E	P	E	E	G–E	E	P	P	P	P
Iron	F–G	F–E	E	P	G–E	G–E	G	G–E	G–E	P	P	P
Manganese	P–F	F–E	E	P	G–E	G–E	G	G–E	F–E	P	P	P
Color	P	F–G	F–G	P–G	—	—	—	—	F–E	E	G–E	G
Taste and odor	F–E	P–F	P–F	P–G	—	—	—	—	F–E	G–E	G–E	P–F
Total dissolved solids	P	P	P–F	P	P	G–E	P–F	G–E	P	P	P	P
Chloride	P	P	P	F–G	P	G–E	P	G–E	P	P	P	—
Copper	P	G	G–E	P	F–G	E	—	E	P–F	F–G	P	—
Sulfate	P	P	P	G–E	P	E	P	E	P	P	P	G–E
Zinc	P	F–G	G–E	P	G–E	E	—	E	P	—	—	—
TOC	F	P–F	G	—	G–E	G	G–E	P–G	G–E	F	F–G	—
Carbon dioxide	G–E	P–F	E	P	P	P	P	P	P	P	P	P
Hydrogen sulfide	F–E	P	F–G	P	P	P	P	P	F–E	F–G	P	P
Methane	G–E	P–E	P	P	P	P	P	P	P	P	P	P
C. Proposed contaminants												
VOCs	G–E	P	P–F	P	P	F–E	F–E	F–E	P–G	F–E	P–G	P
SOCs	P–F	P–G	P–F	P	P	F–E	F–E	F–E	P–G	F–E	P–E	P–G
Disinfection by-products	—	P–E	P–F	P–F	—	P	F–G	F–G	F–G	F–E	P–G	—
Radon	G–E	P	P	P	P	P	P	P	P	E	P–F	P
Uranium	P	G–E	G–E	E	G–E	E	—	E	P	F	P–F	G–E
Aluminum	P	F	F–G	P	G–E	E	—	E	P	—	—	—
Silver	F–G	G–E	P	G	—	—	—	P	F–G	P–F	—	—

P—poor (0 to 20 percent removal); F—fair (20 to 60 percent removal); G—good (60 to 90 percent removal); E—excellent (90 to 100 percent removal); "—"—not applicable/insufficient data

Note: Costs and local conditions may alter a processes applicability.

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FLUID PROCESS CHEMICALS DEPARTMENT
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amber-hi-lites

ION EXCHANGE IN HEAVY METALS REMOVAL AND RECOVERY

William H. Waitz, Jr.

WEAKLY ACIDIC CATION EXCHANGE UNIT PROCESS

Editor's Note

Amber-hi-Lites has now completed 30 years of continuous publication. This milestone is a tribute to the efforts of Dr. Robert Kunin, who wrote the first issue and nearly every one since, and continues to be the principal contributor. We want publicly to acknowledge our debt to him for his guidance and hard work. Dr. Kunin joined the Research Division of Rohm and Haas Company in 1946 and was employed there until 1970 when he became a member of the marketing staff. In this new capacity he served as technical consultant to the company's ion exchange sales and marketing personnel throughout the world. He retired from Rohm and Haas in 1976 and established a private consulting practice. Throughout his association with Amber-hi-Lites, his fertile imagination, his encyclopedic knowledge of the chemical industry and his prolific pen have enabled this publication to grow and develop. We are grateful to him, and look forward to his future contributions.

The first issue of Amber-hi-Lites was dated April, 1949, and differed considerably from our current issue. There were several short items on the front page, covering various news items of interest to the ion exchange "industry." The second and third pages contained three short articles on *Protein Purification, Silica Sorption* and *Bacteria Binding* as well as several abstracts of articles on ion exchange taken from the current literature. The back page was devoted to an advertisement for two new ion exchange resins, Amberlite IRC-50 and Amberlite IRA-400.

There was a short note on the bottom of the front page which read:

"Every publication must have a motive, a plan, a reason for existence. And Amber-hi-Lites is no exception. It will report all the news of ion exchange that it can hold, so that you who now employ adsorption techniques, and you who search for efficient process short-cuts, and you who have only an academic interest in ion exchange phenomena may run and read and file to read again."

This statement of objective is as valid today as it was then. The technology of ion exchange has increased in scope and complexity, and the length and depth of Amber-hi-Lites have both increased accordingly. Short items have given way in this publication to longer, more involved treatises on a single phase or use of ion exchange. Amber-hi-Lites has provided a forum for presentation of new ideas, new products and new concepts, and it has occasionally been the starting point for spirited discussions on various aspects of the art and science of ion exchange between people whose views might differ from those expressed in these pages.

This issue of Amber-hi-Lites features an article on adsorption of heavy metals, written by William H. Waitz, Jr. Mr. Waitz is Market Planning Manager for Industrial Chemicals-North America, located in Rohm and Haas Company's Home Office in Philadelphia. He has had extensive marketing experience, most recently in the field of waste control and sugar processing applications of ion exchange resins.

Gerald D. Button
Editor

INTRODUCTION

Interest in the removal and/or recovery of heavy metals from industrial waste streams continues to increase as discharge limitations become more restrictive. Pre-treatment of wastes prior to discharge to municipal sewage treatment plants is now a reality. In the past, it has frequently been possible to comply with the limitations through the use of precipitation systems. However, as permissible discharge limits are

WEAKLY ACIDIC CATION EXCHANGE UNIT PROCESS

lowered, precipitation will not meet these lower limits. In addition, when working at the usual low concentrations encountered in industrial waste streams, excessive amounts of chemicals are required to effect precipitation and large lagoons are necessary to settle out the resulting sludge. As inflation increases the value of metals, recovery begins to look more attractive. Consequently, there is increasing interest in ion exchange as a part of industrial waste treatment systems.

Ion exchange has been used widely for a number of years in the recovery of gold from plating wastes and for the rejuvenation of chrome plating baths by the removal of Fe^{+3} and Cr^{+3}. The chrome plating installations also use anion exchange resins to recover CrO_4^{-2} ions from the rinse water for return to the plating baths.[1] Recovery of Na_2CrO_4 from cooling tower blowdown for return to the system is another application being used in several large scale operations.[2]

In designing an ion exchange system to remove objectionable ions from waste streams, one must, of course, consider the selectivity of the resins for various ions. Fortunately, the natural selectivity of ion exchange resins favors the larger ions with higher valence. At low concentrations, therefore, both weakly and strongly acidic cation exchange resins will exchange ions of alkali metals and alkaline earths for heavy metal ions. The weakly and strongly basic anion exchange resins have an affinity for the large heavy metal anion complexes such as $Fe(CN)_6^{-4}$.[3]

The major exceptions to this preference for larger ions with higher valence are that weakly acidic cation exchange resins prefer to be in the acid (hydrogen ion) form and weakly basic anion exchange resins prefer to be in the free base form rather than a salt form. As a result, weakly acidic cation exchangers prefer hydrogen ions to all other cations and weakly basic anion exchange resins will shift preferentially to the free base form in the presence of hydroxide ions.

The resin choice in designing an ion exchange system for heavy metals removal or recovery is, of course, dependent upon the goal of the installation. If the removal of a single species is required, then a resin that is primarily selective for that ion, such as a "chelating resin," is called for. If, on the other hand, a variety of heavy metals must be removed, this can often be accomplished with a weakly acidic resin in the sodium form which will replace all the heavy metal ions with sodium ions. Where deionizing and recycling of waste water is of interest, a strongly acidic cation exchange resin in the hydrogen form must be used since it will release hydrogen ions to replace all other cations in the stream.

If one or more of the heavy metals to be removed is present as an anionic complex, an anion exchange resin, usually in the salt form, is selected. This resin will adsorb only those metals which are present as anions; all others present as cations will pass through the resin bed totally unadsorbed.

CHELATING RESIN

Amberlite IRC-718 is a macroreticular chelating resin specifically designed for the removal of certain heavy metals. For most applications, it must be operated in the sodium form and, therefore, cannot be used in total deionization. However, because of its high affinity for Cu^{+2} and Fe^{+3}, it can be operated in the hydrogen form when being used to remove these ions.

The selectivity, relative to calcium, of Amberlite IRC-718 for various cations at pH 4, determined in column experiments under laboratory conditions, is shown in Table I (as below). These values will, of course, be affected by both the concentration of metals and the pH of the stream being treated, as well as by changes in electrolyte and background metal concentrations. Note the resin's much greater selectivity for heavy metals than for calcium.

TABLE I
Selectivities of Amberlite IRC-718 For Metal Ions
ph = 4.0

Metal Ion	$K^{M}/_{Ca}$
Hg^{+2}	2800
Cu^{+2}	2300
Pb^{+2}	1200
Ni^{+2}	57
Zn^{+2}	17
Cd^{+2}	15
Co^{+2}	6.7
Fe^{+2}	4.0
Mn^{+2}	1.2
Ca^{+2}	1.0

The selectivity of Amberlite IRC-718 was also investigated in an ammoniacal stream (pH=9) containing 200 g/l $(NH_4)_2SO_4$. The results are given in Table II.

TABLE II
Selectivities of Amberlite IRC-718
for Metal Ions
(pH = 9.0, ammonia)

Metal Ion	$K^{M}/_{Ca}$
Co^{+2}	83
Ni^{+2}	30
Cd^{+2}	14
Cu^{+2}	10
Zn^{+2}	3
Ca^{+2}	1

Amberlite IRC-718 can be regenerated efficiently with a 4 to 10% solution of a strong acid. Capacities for various heavy metals under a variety of conditions are given in Table III.

[1]Kunin, R., Amber-hi-lites, #104, March 1968
[2]Kunin, R., Amber-hi-lites #151, May 1976
[3]Avery, N.L. and Waitz, W.H., Amber-hi-lites #155, summer 1977

WEAKLY ACIDIC CATION EXCHANGE UNIT PROCESS

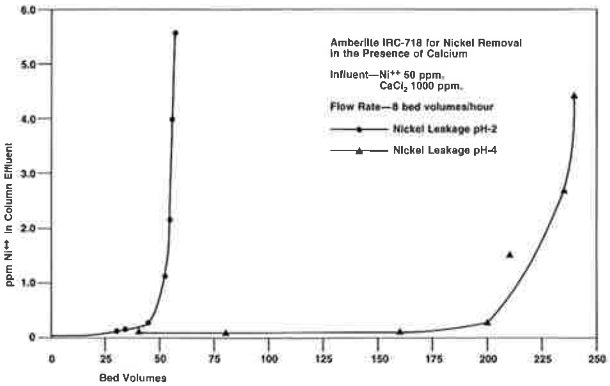

FIGURE II

Equivalent to proposed resin

CHELATING RESIN VERSUS WEAKLY ACIDIC CATION EXCHANGE RESIN

Although Amberlite IRC-718 is often required to achieve efficient heavy metals removal, Amberlite DP-1, a weakly acidic cation exchange resin in the sodium form, sometimes exhibits equal or superior capacity and regeneration efficiency when treating waste streams containing heavy metals. In addition, this resin is less costly than Amberlite IRC-718. Table V and Figure III compare Amberlite DP-1 with Amberlite IRC-718, both in the sodium form, for the removal of zinc from a solution containing 50 ppm of Zn^{+2} and 1,000 ppm of $CaCl_2$ at a pH of 7.0. The flow rate was 8 bed volumes per hour or 1 gpm/ft^3 and removal was essentially the same for both resins except that Amberlite IRC-718 showed a sharper break in the leakage curve after 250 bed volumes.

TABLE V
Amberlite IRC-718 (Na^+) vs. Amberlite DP-1
Influent: Zn^{+2} 50 ppm
$CaCl_2$ 1000 ppm
pH = 7.0
Flow Rate: 8 Bed Volumes/hour (1 gpm/ft³)

	Effluent Analysis ppm Zn^{+2}	
Bed Volumes	Amberlite DP-1	Amberlite IRC-718
86	0.01	0.01
128	0.02	0.01
171	0.07	0.01
214	0.10	0.05
257	0.27	0.22
274	-	0.72
300	0.91	2.44
342	2.28	8.20

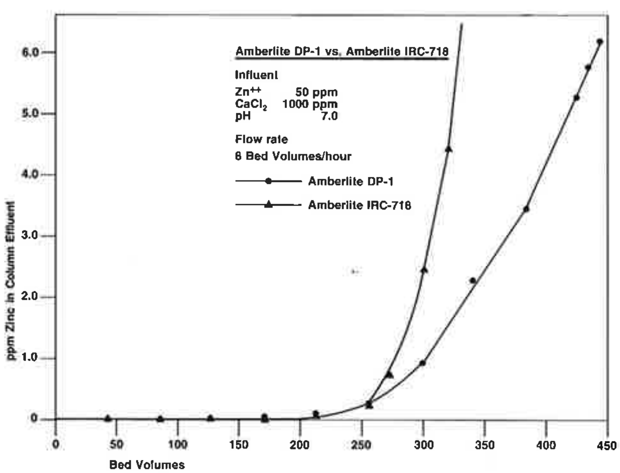

FIGURE III

Table VI and Figure IV illustrate the elution curves for zinc from Amberlite IRC-718 and Amberlite DP-1 with a 10% HCl regenerant at a flow rate of 8 bed volumes per hour or 1 gpm/ft³. It can be seen that Amberlite DP-1 gives a sharper elution curve and is, therefore, the better choice under these particular circumstances.

Table VI
Zinc Regeneration
150 mls of 10% HCL Followed by D.I. H_2O
Flow Rate: 8 Bed Volumes/hour (1 gpm/ft³)

	Effluent Analysis ppm Zn^{+2}	
Bed Volumes	Amberlite DP-1	Amberlite IRC-718
1	6,000	1,560
2	13,950	8,450
3	252	2,400
4	9	1,505
5	1	2,405
7	1	46

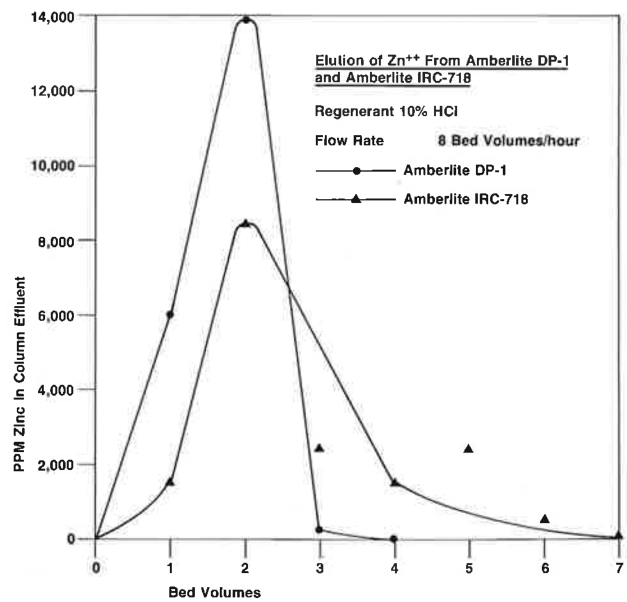

FIGURE IV

In Table VII and Figure V, Amberlite IRC-718 and Amberlite DP-1 are compared for Pb^{+2} removal. In this waste stream the concentration of Pb^{+2} was 50 ppm in the presence of 1,000 ppm of $CaCl_2$ and at a pH of 4.0. The flow rate through the resin was 8 bed volumes per hour or 1 gpm/ft³ The data show the significant advantage of Amberlite DP-1 over Amberlite IRC-718 in this application.

APPENDIX B
Treatability Study

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March 3, 2016

Alan Eudy
Glover Construction
4462 US-301
Pleasant Hill, NC 27866
Phone: (252) 578-7134
Email: alan.eudy@gmail.com

RE: Treatability Study Dominion Dumfries VA

Mr. Eudy

Enclosed is an explanation of the theory behind our water treatment proposal along with the onsite treatability study that was conducted on the Dominion site in Dumfries, VA. Our recommendations of chemistry was based on design, effectiveness, and changing variables that we expect during the life of the project. We would like to take an opportunity to define existing chemistries proposed and tested during the site visit. Many commodity chemistries exist and while effective have limitations. We see many times during standardized bench testing chemistries used will succeed during analysis fail during deployment. ProAct/Carbonair uses an approach to closely replicate onsite conditions during our bench testing that factors in many aspects often overlooked by standardized testing. Finally, our goal is to find green or environmentally friendly chemistries that will give you and your client comfort that minimizes exposure to your team and the ecosphere.

Mitchell Stocki
Applications Sales Engineer
ProAct Services Corporation

Sawang Nottakun PhD
Senior Process Engineer
Carbonair Environmental Systems

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Description of Proposed Wastewater Treatment Process

at the Old Dominion, Dumfries, VA Site

ProAct/Carbonair has proposed a system to treat wastewater at the Dominion, Dumfries, VA site based on the following information:

Maximum flow rate:	2,000	gpm
Average flow rate:	1,750	gpm
Total volume to be treated:	200,000,000	gallons
Water temperature:	55	^oF

Contaminant	Influent Conc.[a]	Effluent Criteria[b] (Monthly Average)	Effluent Criteria[b] (Daily Maximum)	Unit
pH	7.85	6-9	6-9	s.u.
TSS	150	30	100	mg/L
O&G	6.9	15	20	mg/L
Aluminum (total)	17,800	NL	NL	ug/L
Aluminum (dissolved)	280	N/A	N/A	ug/L
Antimony (total)	14	1,300	1,300	ug/L
Antimony (dissolved)	16	1,300	1,300	ug/L
Arsenic (total)	**1,200**	240	440	ug/L
Arsenic (dissolved)	**900**	N/A	N/A	ug/L
Barium (total)	830	NL	NL	ug/L
Barium (dissolved)	380	N/A	N/A	ug/L

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Beryllium (total)	7.2	NL	NL	ug/L
Beryllium (dissolved)	0.18	N/A	N/A	ug/L
Boron (total)	1,300	NL	NL	ug/L
Boron (dissolved)	1,400	N/A	N/A	ug/L
Cadmium (total)	0.27	1.4	2.6	ug/L
Cadmium (dissolved)	< 1	N/A	N/A	ug/L
Chloride	251,000	370,000	670,00	ug/L
Chromium III (total)	16	88	160	ug/L
Chromium III (dissolved)	2.6	N/A	N/A	ug/L
Chromium VI (total)	0.14	17	32	ug/L
Chromium VI (dissolved)	0.12	N/A	N/A	ug/L
Cobalt (total)	16	NL	NL	ug/L
Cobalt (dissolved)	2.2	NL	NL	ug/L
Copper (total)	84	9.6	18	ug/L
Copper (dissolved)	1.9	N/A	N/A	ug/L
Iron (total)	11,800	NL	NL	ug/L
Iron (dissolved)	7,100	N/A	N/A	ug/L
Lead (total)	**38**	14	26	ug/L
Lead (dissolved)	< 2	N/A	N/A	ug/L
Mercury (total)	< 0.2	1.2	2.2	ug/L
Mercury (dissolved)	0.35	N/A	N/A	ug/L
Molybdenum (total)	430	NL	NL	ug/L
Molybdenum (dissolved)	430	N/A	N/A	ug/L
Nickel (total)	**28**	24	44	ug/L
Nickel (dissolved)	8	N/A	N/A	ug/L
Selenium (total)	**40**	8	15	ug/L
Selenium (dissolved)	**25**	N/A	N/A	ug/L
Silver (total)	< 1	2.2	4.0	ug/L

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Silver (dissolved)	< 2	N/A	N/A	ug/L
Thallium (total)	**1.4**	0.94	0.94	ug/L
Thallium (dissolved)	0.65	N/A	N/A	ug/L
Vanadium (total)	7.2	NL	NL	ug/L
Vanadium (dissolved)	< 2	N/A	N/A	ug/L
Zinc (total)	66	98	180	ug/L
Zinc (dissolved)	190	N/A	N/A	ug/L

a) The design influent concentrations are based on the maximum detected concentrations from Pond D and Pond E.
b) The effluent criteria are based on the VDEQ limits for discharge via Outfall 503 to Outfall 001.
Bold values indicate the exceedance of the discharge limits.

NL = No limit

N/A = Not applicable

As can be seen from the table shown above, there are only five contaminants (arsenic, lead, nickel, selenium, and thallium) that appeared to have TOTAL concentration levels exceeding the VDEQ discharge limits. Of these five contaminants, there are only two contaminants (arsenic and selenium) that appeared to have DISSOLVED concentration levels exceeding the VDEQ discharge limits.

The wastewater from the ponds will be first pumped into multiple frac tanks arranged in parallel where gross solids will be allowed to settle. Each frac tank will be installed with a blower which can be used to aerate the wastewater in order to oxidize and convert arsenic that may be in the form of arsenite (As+3) into the form of arsenate (As+5) which can be more effectively removed by iron salt co-precipitation and activated alumina (AA) adsorption. However, we believe that arsenic in the ponds may have already been slowly oxidized by ambient air for quite some time, and the aeration may be unnecessary.

The effluent from the frac tanks will be injected with a cationic and anionic polymeric flocculation aiding agents, and delivered to multiple Geotubes arranged in parallel, where flocs will be allowed to form and settle. The main purpose of this step is to reduce the high arsenic concentration to such a level that the polishing AA media provided downstream can last a reasonably long period of time. Selenium and other heavy metals (lead, nickel, thallium) are also expected to be removed in this step. From an onsite treatability study conducted at the Dominion site, BHR-P50 (hybrid PAC biopolymer blend) in conjunction with LBP-2101 (anionic polysaccharide) were found to be very effective in flocculation and removal of suspended solids in this wastewater.

The filtrate from the Geotubes will be delivered to multiple self-backwashable sand filters followed by small micron bag filters to remove fine particulates that may be associated with insoluble heavy metals. After the flocculation and particulate filtration steps, the wastewater is expected to be relatively clear and should only contain dissolved metals. The clear wastewater will be further treated using AA and a weak acidic cationic exchange resin. The AA will be used to remove residual dissolved arsenic, selenium, and thallium while the resin will be used to remove residual dissolved cationic heavy

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metals (Al, Ba, Cr(III), Cu, Fe (II), Pb, Ni, Tl, and Zn). Although all the dissolved cationic metals are expected to be below the discharge limits, the resin is recommended as a precautionary measure. The resin will not be placed on line unless some of those cationic metals are found to exceed the discharge limits.

On-site Treatability Study

at the Dominion, Dumfries, VA Site

Introduction

The initial testing conducted onsite encompassed the homogenization of the downstream ash pond with the upstream discharge pond currently undergoing a dredge process. Although an exact replication of the water was not possible we looked at various concentrations during the homogenization process. TSS solids from the ash pond had NTU values over 2000 while NTU values from the upstream pond had under 20. The initial analysis took into account the discussion of the treatment train, flow rate, and effluent limitation guideline. For the purposes of this onsite test Particulate size analysis, NTU, pH, Conductivity, TDS, Salinity, and arsenic was measured only. Basic dose response testing was conducted using various chemicals as listed below:

Aluminum Sulfate 48%

Anionic PAM

Catiionic PAM

Chitosan

Anionic Biopolymer Chitosan mix.

Dry anionic PAM mineral blend.

Hybrid inorganic biopolymer blend.

The homogenized particulate size analysis indicated that over 65% of the solids were under 1.5 µm. This analysis gave us the starting point to begin the process of chemical selection. Commodity chemicals such as Alum or other inorganic salts are effective in neutralizing the pronounced –ve charge “Zeta Potential” that encompasses the colloidal particulate allowing for collision, aggregation and precipitation under Van der Waals equation. While effective in supernates that have little velocity these have no sheer resistance abilities and often must be followed by a high molecular weight polymer such as PAM or polyacrylamides.

Anionic and Cationic polyacrylamides are derived from petroleum which gives the precipitates a gelatinous floc structure which is often extremely viscous and stick by nature leading to blinding of any filtrate material weather fabric, sand, or remediation media. Due to the fact that both geobag and sand are proposed in the model both forms of PAM were dismissed.

Anionic Biopolymers were tested both pre & post Alum however because of the solids content the amount of Alum required depressed the alkalinity to levels that compromised the pH. Additionally the resulting amount of un-biodegradable aluminum ion that would be present within the sludge was found

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to be high and additional costs in handling may be high. Buffering the pH could be accomplished but did not seem desirable to the team onsite.

Importantly as rapid clarification and precipitation was during the study floc characteristics were as equally important. In most cases bench testing will use a set standard by mixing at fast and slow rates proceeded by observing the sample at 0 velocity. While effective in determining clarification this doesn't replicate real time events and often the agglomerated flocs sheer apart by-passing filtration measures. Our sampling procedures measures clarification, sedimentation precipitation velocity all while maintaining energy within the container. Finally the precipitate is filtered under pressure rather than gravity to ensure sheer resistance abilities.

Treatability

After the initial dose range finding studies were concluded we focused on two chemistries that gave us the indication for success and cohabitation effectiveness within the discussed treatment train.

BHR-P50 optimized at 100 mg/L. is a hybrid PAC biopolymer blend. The constituents of this chemistry provides the inorganic metal salt that reverses the zeta potential like alum but with 50% less alumni content resulting in little to no pH or alkalinity fluctuations. The biopolymer constituent allows for a more pronounced aggregation and provided the precipitate moderate sheer ability. This blend is classified as a cationic coagulant/polymer.

LBP-2101 optimized post BHR-P50 at 50 mg/L. is an anionic polysaccharide. It's constituent which differs from PAM's form an excellent floc when used in conjunction with a cationic coagulant or polymer. Once agglomerated the floc has excellent sheer abilities suitable for high flow filtration. Due to the fact it is compromised from simple sugar monomers these have effective filtration abilities with no blinding effects. The additional benefit of using these two chemistries in conjunction leave no possible +ve charge entering the surface waters and in fact residual testing can be accomplished onsite. Chemistries using cationic constituents have a much higher Eco toxicity then anionic constituents. This combination leaves with a net neutral charge. +/-.   The proposed chemical model reduced the overall NTU value by 97% with settling alone, filtration combination noted a 99% reduction in NTU's.

The above concentrations allows for flexibility in changing conditions. Our operators will have the capability to monitor and adjust if necessary in real time rather than waiting for outside or offsite lab analysis. No change in pH or other water characteristics were noted. Arsenic was not present in any of the samples collected. Both chemistries are listed as non-hazardous.

APPENDIX C
Conceptual Treatment System Design Basis and Equipment General Arrangement

Customer: Glover Construction
Site: Dumfries, VA
Date: 1/19/16

Design Basis:

Flow rate:	**2,000**	gpm (maximum)
	1,750	gpm (average)
Volume to be treated:	200,000,000	gallons
Water temperature:	55	°F (assumed)

Contaminant	Influent Conc.[a]	Effluent Criteria[b] (Monthly Average)	Effluent Criteria[b] (Daily Maximum)	Unit
pH	7.85	6-9	6-9	s.u.
TSS	150	30	100	mg/L
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Antimony (dissolved)	16	1,300	1,300	ug/L
Arsenic (total)	**1,200**	240	440	ug/L
Arsenic (dissolved)	900	N/A	N/A	ug/L
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Barium (dissolved)	380	N/A	N/A	ug/L
Beryllium (total)	7.2	NL	NL	ug/L
Beryllium (dissolved)	0.18	N/A	N/A	ug/L
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Iron (dissolved)	7,100	N/A	N/A	ug/L
Lead (total)	**38**	14	26	ug/L
Lead (dissolved)	< 2	N/A	N/A	ug/L
Mercury (total)	< 0.2	1.2	2.2	ug/L
Mercury (dissolved)	0.35	N/A	N/A	ug/L
Molybdenum (total)	430	NL	NL	ug/L

Molybdenum (dissolved)	430	N/A	N/A	ug/L
Nickel (total)	**28**	24	44	ug/L
Nickel (dissolved)	8	N/A	N/A	ug/L
Selenium (total)	**40**	8	15	ug/L
Selenium (dissolved)	25	N/A	N/A	ug/L
Silver (total)	< 1	2.2	4.0	ug/L
Silver (dissolved)	< 2	N/A	N/A	ug/L
Thallium (total)	**1.4**	0.94	0.94	ug/L
Thallium (dissolved)	0.65	N/A	N/A	ug/L
Vanadium (total)	7.2	NL	NL	ug/L
Vanadium (dissolved)	< 2	N/A	N/A	ug/L
Zinc (total)	66	98	180	ug/L
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a) Based on the maximum detected concentrations from Pond D and Pond E.
b) Based on the VDEQ limits for discharge via Outfall 503 to Outfall 001.
Bold values indicate the exceedance of the discharge limits.
NL = No limit
N/A = Not applicable

Recommendations:

Aeration Tanks (to oxidize arsenic) Carbonair does not believe this step is necessary
4 – 21,000 gallon tank

Injection Trailers

- Includes automatic injection capabilities for pH Adjustment, Flocculation and $FeCl_3$

Ferric Chloride ($FeCl_3$) Injection (to produce iron flocs for adsorption of arsenic)

10-gph injection pump

- We recommend that $FeCl_3$ be initially injected at a dosage of 10 ppm. The required injection rates of the 20% by wt solution are calculated to be 4.2 and 3.7 gph at 2,000 and 1,750 gpm, respectively.
- The initial 40% $FeCl_3$ solution consumption rates are calculate to be ~ 50 and 44 gpd at 2,000 and 1,750 gpm, respectively.

PolymerInjection (to enlarge iron flocs for adsorption of arsenic)

10-gph injection pump

- Exact polymer and dosing to be determined by bench testing

Flocculation/Settling Tanks/Basins (to allow iron to form flocs to adsorb arsenic)

Sand Filters (to remove suspended iron flocs)

Four Model 4-54 sand filters in parallel, each Model 4-54 comprising four 54-inch diameter filters in parallel

- Each filter in Model 4-54 will be backwashed with treated water from the other three filters for at a backwashing flow rate of ~ 250 gpm for 10 minutes. During the backwashing period, the total flow rate through the four Model 4-54's should be reduced to ~ 1,500 gpm.
- We recommend that the backwash water be delivered back to the ponds.

Post-Filters (to remove fine particulates)

Four Krystil Klear Multi-Round Model 3636 bag filter housings (1-micron high efficiency) in parallel

- The post-filters are recommended for the removal of fine particulates, which may be associated with any heavy metals.

Activated Alumina Adsorbers (to remove dissolved selenium)

Four PC78's in parallel, each vessel filled with 500 ft^3 (20,000 lbs) of granular activated alumina (AA)

- Assuming all the dissolved arsenic to be removed by pre-treatment upstream , all the four vessels are predicted to last ~ 598.4 million gallons of water or **208** days of continuous operation at 2,000 gpm.

ARSENIC REMOVAL SYSTEM

Carbonair

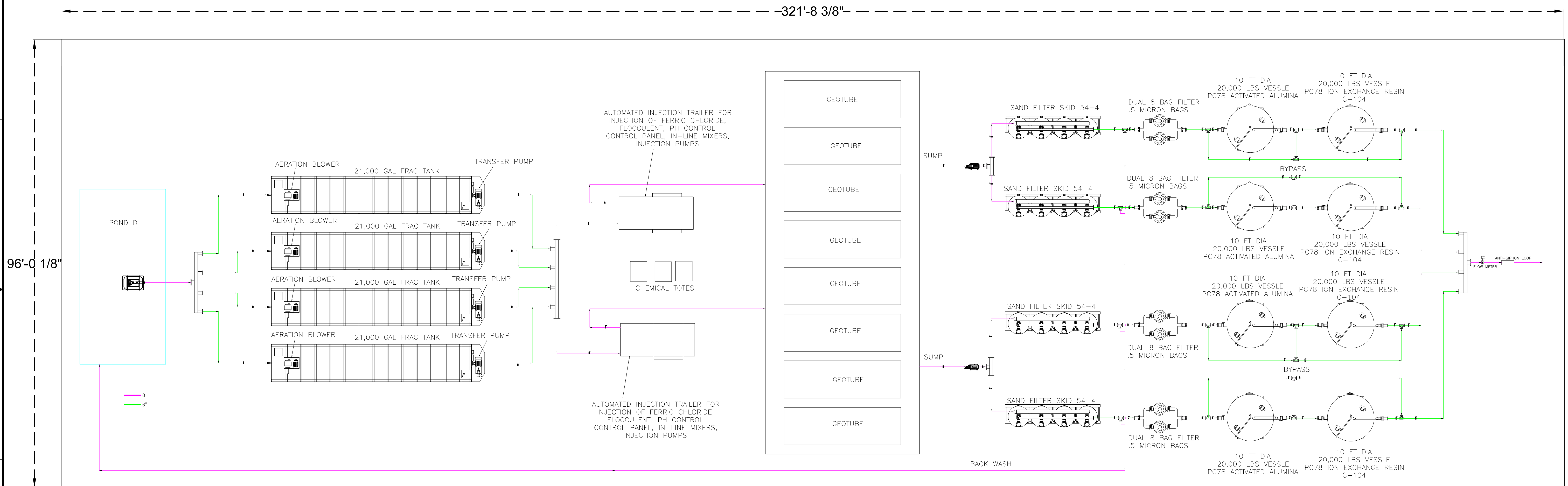
1480 County Road C West, Roseville, MN 55113

Phone: 800-526-4999 Fax: 651-202-2985 www.carbonair.com

Project name:	Dumfries, VA	
Flow rate:	2000	gpm
Total selenium (as arsenic) concentration:	25	ppb
Arsenite (AsIII) concentration:	Unknown	ppb
Arsenate (AsV) concentration:	Unknown	ppb

Adsorber model:	PC78	
Number of adsorbers:	4	
Adsorber arrangement:	In parallel	
Type of adsorbing media:	Activated Alumina	
Media bulk density:	40	lbs/cu.ft.
Volume of media in each adsorber:	500	cu.ft.
Total volume of media:	2000	cu.ft.
Total mass of media:	80000	lbs
Preoxidation:	Yes	

Estimated treatable volume of water (with preoxidation):	598,400,000	gal



ITEM	QTY	DESCRIPTION	MANUFACTURER	MANF NO

REV	DATE	DESCRIPTION	DRW	APPR

DRAWING NO. 1

SIZE B

SCALE NTS

REV

MATERIAL

CUSTOMER

DRAWN BY JONATHAN DIPPLE

DATE 2/1/16

SHEET 1

JOB NO.

UNIT NO.

ProAct SERVICES CORPORATION

PLAN VIEW
2000 GPM WTS

00022416